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MIRROR OF NATURE

A

BOOK OF INSTRUCTION AND ENTERTAINMENT

TRANSLATED FROM THE GERMAN

OF

G. H. SCHUBERT

BY

WILLIAM H. FURNESS.

PHILADELPHIA
THOMAS, COWPERTHWAIT & CO.
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ADVERTISEMENT.

The author of this work, known in his own country as an eminent naturalist, a veteran devotee of science and philosophy, and a traveler in the East, in a brief and modest preface, states it to be the design of this volume to furnish "riper youth" with important elementary knowledge, and in as pleasing a manner as he was able. A friendly and religious spirit breathes from its pages. Like all works of its kind, it tends to elevate the reader's apprehensions of the Infinite wisdom. To all young inquirers, in whom the appetite to know is awakened, this translation is dedicated. Two or three chapters, which seemed not to be important, have been omitted. The accurate and thorough scientific knowledge of a young friend, to whom this translation has been submitted, authorises the anticipation that no material errors will be found in the scientific phraseology of the work.

W. H. F.

December, 1848.

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MIRROR OF NATURE.

PART I.

THE IMPULSE TO BEING AND KNOWING.

1. ALL WANT SOMEWHAT.

When we consider particularly the living creatures on this earth, animals and plants, we may say of them: "These are beings in continual want of something." Not so is it with a marble statue; it neither hungers, nor thirsts; is neither too hot nor too cold; it needs no breath to draw, it suffers in none of its members. And so would every stone, if it had power and understanding to speak, say to us: 'I am content, and desire nothing.' To us, human beings, on the contrary, like the animals, now one thing, now another is wanting. The ever-active bird of the wood has always something necessary to do; now it is driven from its nest by hunger, and then again by thirst; thousands of times in a day it must inhale fresh air, or be suffocated; at evening, when the sun goes to rest, the bird seeks the darkness and the refreshment of sleep, and again when night terminates, it is allured by the morning light and the delight of waking day. And to this daily and lesser pressure of want, comes a much greater pressure every year; for in spring the bird has to provide for its young, in autumn it must wing its way over the waters to far lands, and seek subsistence for the winter.

As with the bird of the wood, so is it with every animal, an even every plant. For even plants require nourishment fro the air and the ground; they must have warmth and light, i they are to live and flourish. The weed of the field, the anima and man, are herein alike, that they all together have to bea their proportional weight of bodily wants and necessities.

But although this weight sometimes becomes a burthen, ye none of us would be without it; no one would be always con tent and without any want, like the stone. For when I ſee nothing more of winter's frost and summer's heat, when I n longer hunger, nor thirst, when my lungs no longer crav breath, then I cease to live. As the hand of the clock stand still, when the weights, which set the wheels in motion, ar taken away or have run down, so too the course of life stand still and is at an end, when no need is felt of a somewhat whic satisfies the want of life; life supports itself only by a constan alternation of asking and receiving, of desire and gratificatio To all living beings, now this, and now that is wanting; but i is also richly provided that they all, each according to its mea sure, receive what they require.

2. WHAT EVERY ONE DOTH WANT MAY BE HAD WITHOUT COUNT.

Were the question to circulate: What does every one nee for the support of life? how various would be the answers The rich inhabitant of the city, used to a hundred conve niences and enjoyments, would think he could not possibly live without various dishes of flesh and vegetables, wine an other drinks, without pillows and matrasses at night, and silk and wool for his clothing, and a comfortably furnished room for his usual dwelling. The poor inhabitant of a mountain village asks much less; he is content if he has bread and potatoes, water on work days, and perhaps a draught of beer

on holidays. On his bed of straw he sleeps more soundly than the rich man; under a coarse frock his heart beats as cheerily, yes, and oftentimes far more so, than the heart of the great man covered with ribbons and badges of honor.

But if now, these two, the poor mountaineer and the effeminate citizen, were on shipboard together, and the vessel were to be wrecked, and they were to be thrown upon a rock in the sea with nothing to eat or drink, nevertheless sustained by the hope of rescue they would be cheered for awhile, for they would still have that which is more necessary to the support of life than meat and drink, bedding and clothing, namely, *the air*, which no human being, be he rich or poor, young or old, can go without even for a few minutes.

In regard to other animals, the variety of things which they severally prefer, is much more striking. The eagle and the lion in a garden full of fine fruits and vegetables, or on a meadow of grass and clover, would starve; they require fresh meat and blood for their nourishment; and must often seek far and wide, and with trouble, the food which the lamb in his grassy garden finds close by, and without trouble; the stork prefers the flesh of frogs, of lizards, snakes, field mice and grasshoppers, before all other food; his kinsman, the crane, on the contrary, values a vegetable diet, with small insects. The thorny plants, on which the camel regales in his poor wastes, would not, if they grew in our vicinity, be touched by horse or deer. The huge whale contents himself with those tender and gelatinous dwellers of the sea, which the greedy shark, and even inferior fishes of prey pass without notice. And thus animals differ in regard to their food as much as they differ in kind and form, in dwelling and birth-place, but there is *one* element of subsistence which they all, without exception, require, without which the lion can no more live than the mouse, the deer than the snail, and that is the air, which like meat and drink, is not first introduced into the stomach, in order thence to pass into the blood,

but penetrates directly to this element of animal life. A animals, call them what you will, seek they their nourishmer in the fields or forests, in the sea or on the land,—all mus breathe, if they are to have power to move—to eat and t drink,—in a word, to live.

But to that indispensable element, which animals as well a men, not only gladly enjoy, but *must* have for their life an support, the old saying directly applies,

> Where our power is much too small,
> Help ever comes without a call.

If the people of Naples, who think they can get through no day in summer unless fresh ice is brought to them over the bay from the mountains, had to wait as long for the fresh air which fills their lungs at every breath, as for the ice, there would soon be an end for them, not only of all enjoyment, but of life itself. Indeed, if the swiftest bird had to fly as far for a breath of air, as he does for a drink from the brook, which flows through the wood, he would perish before he got half way. But for this necessity, returning not daily and hourly, but every instant, the most thorough and ample provision is made in the grand economy of nature. For air is everywhere, where dwell living beings, upon the heights and in the depths; it rushes of itself into the lungs of the new born child, it finds admission to the little ball in the egg through the fine openings at the thick end of the shell; it sinks down in the water to the lowest deeps of the sea, and is there breathed in by water-animals; in all hollows and open caverns of the earth, and even into the interior of vegetable and animal substances, the air penetrates, and fills the same.

Thus the air, which surrounds and penetrates all living beings, reminds us, like an image in a mirror, of the all-upholding Providence, in and by whose ministration, the whole creation subsists, in whose creative power we all live and move and have our being.

3. THE HOUSE-KEEPER.

Another image in the mirror of Nature: the image of a good house-keeper, presents itself to us in *Water*. Without water the whole surface of the earth would soon become a waste, like the African deserts in the dry season of the year; all vegetation would wither, all animals perish. But like a careful mother, who visits, without ceasing, all parts of her house, now the cellar, now the upper store-rooms, in order to provide for her household whatever they need,—so Water flows in brooks and rivers down into the sea, thence ascends after a space into the air as vapor, divides itself into the drops of the dew, pours down its blessing in rain upon the thirsty land, collects itself on the cool mountains or on the wooded hills, in springs and brooks, and again distributing its gifts as it passes, runs into the sea. Water follows the miner into his mines, the crystal-digger upon his bald mountain heights; for just as air penetrates water and mingles with it, so water, in an airy form, penetrates the atmosphere and gives drink to Alpine plants and mosses in such fulness that the midday sun can scarcely drink up the pearly drops. There only, where no weed flourishes, and no thirsty life can be supported, on the cold heights, which only aeronauts and bold mountain travellers reach, does water appear to be relieved of its maternal cares, there water hardly comes; there it is that the air is more void of water than elsewhere.

As in a mother's lap, the tenderest and finest creatures are kept and hidden in the water, the polypus, who constructs the coral fabrics, and the manifold forms of the medusa or sea-nettle. The most imperfect forms of the animal kingdom, from which apparently the higher and completer forms of land-animals are produced, are folded in the maternal bosom of the water.

Water indeed abounds on the earth, for more than thr quarters of the surface of the globe are covered by the ocea and streams; lakes and swamps also are found in differe regions in great numbers. Nevertheless this beneficent el ment does not come of itself, like the air, to the land-animal who thirst for it. It must be sought out by them, often a great distances and with difficulty. For the vaporiform wate which floats in the air, does not slake their thirst, and the sal water of the ocean, which would only increase it, is mostly unpalatable. But for this purpose the bird has his wings, th land-animal his strong feet, that, with these helps, they may seek what they want; and in a few moments the swallow, tha has its nest in the rocky clefts of Arabia Petaæa, may, wher impelled by thirst, reach the pool in which, from the time o the rainy season, water has been preserved; the herds of the swift-footed African gazelle go from place to place, following the rain-cloud as it now here and now there pours down its abundance, and every morning as well as every evening they find themselves, however far they graze, at a watering place.

Quite otherwise than with the animals, is it with the productions of the soil. Plants cannot leave the spot where they exist, to go in search of water, they must wait until it comes to them. And yet they need water more than animals. For the latter partly find wherewith to allay their thirst in the juices of their food; the bird of prey finds it in the fresh flesh and blood of its victim, the ox and the goat in the stems and leaves of weeds. In the case of plants, on the contrary, water is not merely an addition to their food, but it is the chief means of nourishment, like its mother's milk to the suckling. The tender babe, how wretched were it, if it had itself to seek out its nourishment, the babe, who can neither stand nor go, but must wait in its swaddling clothes, until its mother gives it to drink. And it does not wait in vain; love impels its mother

to it, more powerfully than it is impelled by hunger towards its mother.

As with the infant, so is it with plants, not only does the water, flowing on the ground, penetrate to their fine root-fibres, but like milk to the new born child, so is the vaporiform water, which, with other aerial nourishment, floats in the atmosphere, and supplies the plants that are fed by it. As the mother, uncalled and of herself, seeks her babe, so water comes down to the plants from the air; where woods abound and the verdure is rich, there springs and brooks abound, and the rain-cloud moves always towards countries rich in vegetation: but where man, in his impatient cultivation or in his barbarism, has stripped the hills and vallies of their woods and shrubbery, there springs and streams dry up, and the land becomes an arid waste.

Thus that Providence, which cares for all creatures,—the love of this good mother,—cannot withhold itself from the plants, which, without eye or ear, or any recognising sense of their nourisher, can do nothing but vigorously suck in the food she offers them. As the eagle carries to her young the food which they cannot of themselves obtain, so long as they lie weak and unfledged in the nest, so He, who gives to all their being, sends to his most helpless creatures that which they need in its time. It is rightly said:

> The strong their own providers are,
> The Lord for weakness taketh care.

4. LIVING FOUNTAINS.

As a supplement to what we have just said of the gift, which is bestowed upon the vegetable kingdom to attract the water from the air and convert it into sap and strength, we will adduce here some instances, from which it appears that that

invisible nourishment, which plants receive, becomes even fi other living beings a visible and refreshing gift.

In the hot coasts of Sierra Leone there is a plant, whic winds itself round other plants, "*the drinking-vessel plant* (*Tetracera potatoria*,) which the natives use as a living wate fountain. For when the fresh stem or leaf of this plant is c through, there flows out an abundant quantity of clear, plea ant water. In the great *water-fountain-tree* (*Phytocrene g gantea*,) in the East Indies, the people there have a simila self-filled drinking cup, and a similar property is observed i various other plants. In the leaves of the bag-bearing Neper the, which grows in Ceylon and the Moluccas, there are lon sack-shaped vessels, which are filled with a pleasant tasting refreshing water. Six to eight of these bags suffice to quenc very great thirst. From the young twigs of a Brasilian *Cæsa pinia* there trickles water without cessation, like rain.

But the most wonderful of all is the power of changing th vapor of the air into liquid water, possessed by some of thos plants, swollen with sap, of the family of the *torch-thistle* which grow upon lava rocks and other soils, in which not th smallest drop of moisture exists for their roots. The melon shaped torch thistles (Melocactus) grow and flourish in th hottest portions of America. When in the dry season every other green thing is withered and dead, when the beasts o the desert pant in vain for water, and far and wide not a drop is to be found, then in the interior of the Melocactus water exists in abundance. The fleshy texture of its stem is com- pletely filled with a watery sap. The herds of wild horses and oxen scent the refreshing draught, and know how to pro- cure it, while, before they touch their mouths to it, they en- deavour to break away with their hooves, the strong sharp thorns with which the surface of the plant is covered, in which attempt indeed many of the thirsting animals become for a long

time lamed, the thorns penetrating their flesh. But these thorns, so annoying to the animals, appear to be furnished to the plant that, in the dry season, and on the arid soil in which it grows, it may not itself suffer for want of water, for these sharp points, which stand forth like little conductors, are in all probability of essential service in attracting and appropriating the atmospheric vapor.

Many plants, through the quality of their sap, may be represented as the sucklings of Nature. The American *Hoa-hya* tree, when an incision is made in its young growth, affords a fluid which, in taste and quality, so closely resembles rich milk that it may be used as cream with coffee or tea. Even in the common Cow-tree, (*Galactodendron utile*) there is a milky sap, which contains, however, instead of a butterish fat, a waxlike substance. Without any trouble man receives from the fruit of the Oil-palm, (*Elais* and *Alfonsia oleifera*) a pleasant tasting oil; from the fruit of the butter-tree a butter is obtained, useful like that obtained from the cow; the bare sap of many palms becomes after a few hours an exceedingly refreshing, wholesome, wine-like drink. As the above mentioned *Hoa-hya* tree affords cream to the lovers of tea and coffee, so there is in the hot regions of America, another plant (*Lippia dulcis*,) which secretes from its surface a sugar, which is so pure that without further trouble one can have it, equal to the best artificially refined juice of the sugar cane.

For the preparation of those nutritive substances for man and beast, of which besides those just mentioned, the vegetable world produces yet many thousands more, no material is needed, as we shall hereafter more particularly consider, but the vaporiform or liquid water from the air or soil, and a few other elements contained in the air or soil or mingled with the water, among which the most important is Carbon, to be described in the sequel. With our art and science we are not able to pro-

[illegible] like the Melocactus [illegible] the air in a barren [illegible] kingdom are a miracle [illegible] miracles. W[illegible]

[illegible] [illegible] [illegible] [

eating secret from the eyes of other beings, and who take their food from a plate which others never share. This order, as we have already seen, is the vegetable kingdom. More carefully than ever Brahmin concealed his eating-room from curious eyes, the tree hides its food-taking roots in the depths of the soil, and what eye of man or falcon has power to discern the aerial substance, on which, as we have just seen, the torch-thistle feeds when it unfolds its leaves full of sap, its beautiful flowers, and its fleshy fruits on the dry rock? Obviously is it forbidden to man and beast to eat from one and the same dish with the tall palm, for neither of them could be satisfied with the dew or the damp mouldy earth. The table, at which, through the kindly powers and juices of the earth, the vegetable world is feasted, so that the grape produces wine, the wheat its grain, is and remains for guests of our order inaccessible and hidden.

But to most of the tables of the animal kingdom access is indeed permitted to our observing eyes, and here the arrangements of the great refectory are more intelligible. Here the first thing to be noted is, that to the small and the frail, who cannot go of themselves for their food, food is brought, and placed in their mouths. To the young bird, who lies weak and unfledged in the nest, the love of its parents renders this service; for such animals, who must go without parental care, and yet who cannot move from place to place, a love cares, which is mightier and more comprehensive than the love of any parent. The oyster, like many others of similar species, sits fast bound to its rock; it has neither eyes nor any other organ peculiarly belonging to a body, nothing but a mouth which craves food, and a body which needs nourishment; nevertheless it has only to open its shell to receive what it wants. The little worm, whence comes the hazel-nut beetle, would be poorly off, if it had to go far with its small stumps of feet for its food,

duce any thing thus; we cannot like the Melocactus procure ourselves a water fountain out of the air in a barren waste. All such works of the vegetable kingdom are a miracle of Creative Power, and science performs no miracles. We must here confess,

> What is giv'n we freely use,
> But how it comes no one knows.

5. THE UNIVERSAL REFECTORY.

What human preparations for the comfort and entertainment of guests are at all to be compared with those which our Creator has established and arranged for his creatures here upon earth? Every moment by day and night, millions of living beings are feasted; many guests come late, others come early, and always it is so arranged that the food, destined for each, stands ready and prepared just at the moment he appears. Here the great as well as the small, the strong as well as the weak are filled; and even the sick find every thing which can strengthen and heal, placed near at hand; before the want is felt the supply is provided.

What was all the fulness of Solomon's palace to the fulness of the grand economy of Creation, and yet nothing is ever wasted; not a crumb, nor a drop goes unused; for every, even the smallest gift of Nature, a consumer is found; what the great leave, the small find a use for; what one rejects, another seizes, what is offensive or poisonous to some, serves for substantial nourishment to others.

Among the inhabitants of India, who still adhere to the old idolatry, a custom exists, that no one, who is not of the same caste, shall see a Brahmin eat, much less eat with him from the same plate or drink from the same cup. There is upon our earth an order of living beings who keep the time of their

eating secret from the eyes of other beings, and who take their food from a plate which others never share. This order, as we have already seen, is the vegetable kingdom. More carefully than ever Brahmin concealed his eating-room from curious eyes, the tree hides its food-taking roots in the depths of the soil, and what eye of man or falcon has power to discern the aerial substance, on which, as we have just seen, the torch-thistle feeds when it unfolds its leaves full of sap, its beautiful flowers, and its fleshy fruits on the dry rock? Obviously is it forbidden to man and beast to eat from one and the same dish with the tall palm, for neither of them could be satisfied with the dew or the damp mouldy earth. The table, at which, through the kindly powers and juices of the earth, the vegetable world is feasted, so that the grape produces wine, the wheat its grain, is and remains for guests of our order inaccessible and hidden.

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but, like the boy in the story, who was enclosed in a huge pan-pie, upon whose sweet walls he fed at pleasure, until he ate himself out into daylight, so the little worm sits in the centre of the sweet kernel, and needs only to gnaw, without moving from the spot. And in similar ways is their daily food placed right before the mouths of most of the larvæ of insects, or easily within their reach.

But not merely for the helpless among the so-called lower orders of animals is an arrangement made by which help comes to them of itself, but even for creatures of a more perfect structure, with difficulty going on foot, or in any other way prevented from obtaining their food as easily as other animals, infirmaries and other provisions are made, by which they are greatly assisted. The sloth is a bad walker, and would suffer greatly from hunger and thirst, if obliged to seek his nourishment on the ground. And for him trees of abundant foliage, upon which with his long claws he can easily climb and fasten himself, are provided as hospitals, where the plenty of leaves that serve for his food lie close to his mouth. The Ant-bear, or Tamandua, requires for his support neither leaves nor fruits, —he lives on insects. But what would it avail him if he had to run after those little lively creatures with his clumsy, long-clawed feet? For this invalid are set, in the midst of the desert, many tables, and so richly loaded with food, that he has only to place himself at them, to eat his fill without trouble. These are the ant-hills, which he digs up with his long claws, and then extends his sticky tongue into the swarm of little, excited creatures, and when in a few moments it is thickly covered with ants, he draws the living mouthful into his mouth, where they instantly cease to live, and consigns them to his stomach.

Even among birds, which, however, are provided with wings as well as feet, the obtaining of their food is, for many species, assisted in a very remarkable manner. How convenient, for

instance, for the heron, who needs much, and in comparison with the Spoon-bill has but little skill in fish-catching, is this operation made, by the fact that the small fish, for whom the natural secretions of this bird are a dainty, as soon as the heron enters a pond collect in schools around his feet, and offer themselves voluntarily to their hungry guest.

The animals who go in search of food by night, or in the twilight, also enjoy their privileges. The bat has but little time for its chase, for during the long winter nights it sleeps, and in summer, when it has to provide for itself and its young, the nights are short. But its nightly hunt is all the more successful than that of other animals who live upon insects, and seek their prey by day. For in the twilight and nightly gloom there is provided the fat, substantial meal of the twilight or night-butterflies, the moths, as well as a variety of beetles. The owl, whose hunting district is overrun during the day by many other birds of prey, comes forth only when the other guests have eaten and betaken themselves to their homes. Nevertheless regard is had for this late guest, and for him, whose eye reaches not like the falcon's into the distance, the best and most wholesome morsels in the neighboring fields and meadows are reserved in such abundance, that the brief period of twilight suffices for him to obtain sufficient food for himself and his young. For just then, at nightfall and in the grey of day, or by moonlight, the most delicate game, the herds of field mice, come abroad, and fall an easy prey to the screech-owl, while the great-horned owl with equal success hunts the wild rabbits, and even the young roes.

It is not indeed the audible sound of a bell that summons the guests at the appointed hour to their table—to the prepared feast, but the call which draws the animals whither provision is made ready for them, must be far more powerful and perceptible than any addressed to our senses, for it extends far

over land and sea, through all the regions of the earth. It is understood by them not through the ordinary, external senses, but by another and inner sense (see ch. 7). For although the bird of passage has eyes which see far into the distance, together with acute powers of hearing and smelling, yet his senses can help him little or nothing when the winter comes, which sweeps away from his dwelling every thing which is necessary to his support. When he sits upon the top of the highest tree or rock on the sea shore, and looks far out over the waters, he cannot descry the land which is to be his abode for the winter. Even the bird in his well-kept cage, where he has nothing to suffer from the autumnal coolness of the air or the disappearance of his means of subsistence, is so seized with the impulse to wander that night and day he has no rest; the young cuckoo, that has never seen its own parents, so soon as he can escape from the confinement in which man holds him, flies, led by the migratory impulse, straight toward the south, to a warmer land. Surely this impulse to the feast of life, reaching the wanderer in a distant region, extends over much wider spaces than that which opens the shell of the firmly fixed oyster to its food, and directs the food to it; but both the bird and the oyster blindly obey the call which comes from no other than that creative power which called both into being.

As to the different dishes wherewith, in the grand refectory of Nature, the several kinds of animals are regaled, they are in their quality and composition as various as the guests that partake of them. To the animals particularly, who live on the land, the vegetable world is first and in general assigned, for their nourishment. For, if there were no plants, then the means of subsistence would shortly disappear even for those animals who live upon the flesh of animals fed on vegetables. It is plants especially, that communicate to animals the juices and powers of life which they obtain at their own hidden and

mysterious meals, (see p. 11,) and not only on land, but also in the sea the vegetable kingdom, in the various kinds of sea weed, has this use for the animal world.

Plants, if they are only in the element adapted to them, in the water or the air, and enjoy the degree of warmth and of the sun's light which is beneficial to them, find everywhere what is necessary to their support. For water and the other substances of the air and soil, which serve the vegetable world for nourishment, are everywhere the same, in the north and the south, the east and the west, and there is no further preparation of them necessary than that which light and heat effect. The animal world makes other demands on the means of nourishment. Almost every species of animals requires to have the food of which it is to partake, first prepared in a particular way, in the vessels and the kitchen of a vegetable or animal body. Let there be set before us human beings, or even before the dogs and sheep, instead of the usual midday meal, a soup made of water and the substances, (such as carbon and nitrogen, ch. 24,) found in the earth and air, and neither of the three, man, dog, or sheep would touch it, but starve before full dishes. But when the same articles are cooked in the bodies of vegetables, into the leaves and stems of grass and clover, into the mealy substance of the potato, into the grains of wheat, or the fruit of the vine and fruit tree, or when in the still further process of transmutation in the stomach, perhaps of the cow, they become blood and flesh, milk and cheese, then sheep, as well as dogs and men readily become fed and satisfied therewith.

Many kinds, particularly of the less perfect animals, require always only one and the same kind of food, as perhaps the leaves and fruits of this or that vegetable, and only when hard pressed do they resort to any other plant, in which they find juices prepared similar to those of their favorite vegetable.

Other animals have a nicer taste; they love and seek the alternation of several dishes, find their food in the most opposite kinds of herbage growing in the fields and meadows; and man desires, together with various vegetables, grains and juicy fruits, which serve him for refreshment, oftener still an admixture of animal food, flesh, milk and eggs.

In satisfying such manifold desires, man succeeds indeed very easily, he uses not only the hands of other men who gather, cook, and bake for him,—and the civilized European receives from all quarters of the world what he needs from strange hands,—but even animals must help to procure for man, what he requires for his kitchen. For him the falcon hunts in the air; for him the cormorant catches fish, with a metal ring placed round his neck to prevent his devouring the prey; for him the dog hunts game or searches for the truffle-nuts hid in the ground, the bee must yield to man a portion of his honey, and the little four-footed forestaller, the hard hearted marmot, give up his granary. But not only man, even the animal here and there supports his life by making other animals cook, or at least labour and gather for him. The herds of the leaf-louse sit on the tender bark, on the leaves and hulls of the buds of many plants as on a green meadow, and suck so diligently that their tender bodies, like the udders of the milch cow in a spring pasture, are distended with juice. This abundance furnishes the ants with nourishment for their young. Touching gently with their feelers the little tubes which project from the end of the back of the leaf-louse, the little milkers gather the nourishing fluid in their mouths and convey it to their hungry foster-children. There are among ants, as among men, a certain species (of another rank as it were,) which are taken into the service of others, laboring and building for them, and even having the care of their young committed to them. The honey-cuckoo of Southern Africa makes even

man his servant in laying open for him the closed treasure-chambers of the wild bee. Even among the birds, who feed on fish, there are some who employ other water-birds to fish for them, rending the prey from these their servants, even after the latter have transferred it to their own maw.

Such cases, in which one animal uses the superfluous gains or the powers of another for its own subsistence, produce no disturbance in that wonderful order which reigns in the grand and beautiful nursing institution of Nature. There, to every guest his own table, as well as his own mealtime is appropriated; while the long-necked Giraffe finds his food high from the ground in the leaves and branches of the Acaccia tree, the tender, timid gazelle is nourished by the herbage which grows at his feet. For the latter the juicy leaves of the high-growing trees grow green in vain. He cannot reach them; for the Giraffe, on the contrary, to bend down to the ground for its food would be insupportably irksome, while in aid of its high-placed head, which reaches into the leafy shelter of the trees, comes the long tongue with which the animal, as with an extended hand, draws down the higher branches to its mouth. How entirely undisturbed by other guests does the snow bird, that sometimes visits us in the winter, take its food, when, obeying the impulse of its nature, it wings its way in summer to the sea cliffs of the far polar regions, on which, during the brief warm season a millet-grass grows, and blossoms, and ripens its seeds, of which the swarms of snow birds are almost the only consumers. When the cross-bill, moved, not perhaps as is supposed in regard to many birds of passage, by the warm air blowing towards him, not by a scent which affects his organs of sense, but by an impulse stirring in the depths of his own being, is led in the winter from afar to his home among the pines where now the seeds, still enclosed in

the cones of the firs or pines, are ripening, then is he too, at such a season, almost the only boarder at his table.

It would seem desirable that, along with these harmless guests, to whose nourishment the superabundance of the vegetable kingdom is assigned, there should be no plunderers, that intrude not only upon their meals, seizing a portion of the same, but also upon their eggs, their young, and upon these innocent creatures themselves. In the vicinity of the snow bird, near the polar ice is found the northern falcon, in the neighborhood of the cross-bill, the martin, of the giraffe the lion. Everywhere the war-cry is raised by the flesh-eating animals. Nevertheless this also belongs to the order of the great economy. For apart from the fact that a great part of living animals, who resort as guests to the table spread with animal food, choose only the dead and mouldering, the family of the beasts of prey must serve as dams and bulwarks against those other parts of the animal world, in which a constant tendency exists to superabundance. Just as dams and dykes guard lowlands from the overflow of streams and seas, so beasts and birds of prey are appointed for the protection of fields and meadows, and indeed of the whole vegetable world. The disproportionate increase, here of this, and there of another species of forms and beings is thus kept within due bounds, so that always at the right time and place a devouring animal appears, which discharges its office, like the owl for instance, that, with its associate guests at the same table, sets limits to the excessive multiplication of field mice.

In the building of a temple, reared and completed by man, the masses of wood and stone, destined to compose its parts, are hewn by human hands, and to every piece the proposed shape is given which shall fit it to the other parts of the edifice. One piece is taken from this rock or forest, another from that,

one is wrought and fashioned here, and one there, and when the time comes all the parts are carried by human hands to the place of building, and through human art fitted together. Quite otherwise is it in the building of the grand temple of the Creation, which, in its constant renewal, testifies without ceasing that the master-builder who laid its foundations in the beginning, still lives and is busy in the midst of his work. In this great edifice the parts fashion and measure themselves, inasmuch as the eater sets his limits to the superabundance of that which he consumes; they move from their places and unite themselves together, after a wisely arranged plan, because that, which in the inanimate stone announces itself as the force of gravity, in them has become a force impelling the individual towards the collective life of Nature. For the stone, as soon as it is removed from its resting place, continues falling or rolling down until it has again found repose in harmony with all; so the motion of living beings continues, without cessation, until every individual finds the place which, for its support and nourishment, is assigned it in the creation. In the various expressions of the force which guides the animals, at the right time and place, to the food prepared for them, we may in a manner discern what the source of all enjoyment is. It is as if every living being, in the moment when it is thus guided to its end, felt the nearness of its Creator, who opens his kind hand and satisfies all that live with blessing.

When we rightly consider these, and all the other characteristics of the wise adaptations of the great structure of the visible world, the want, which, as we said in ch. 1. every individual being suffers, appears in another light. All beings want somewhat, but it is well for them that they do, for Want moves them, like the controlling force of that power, which embraces and holds together all things, and brings them, each according to its measure, into a kind of communion of their

being with the power and love of the Creator himself. In a manner, indeed only figurative, we see here presented in animal natures something similar to that which is expressed for the human mind in the proverb: Want teaches prayer.

6. HOME-SICKNESS.

When the stone, or any other inanimate body is taken from the place where it rested, and then set in motion in another, perhaps far distant place, it continues in that motion till it has again found a halting and resting place. To the force of gravity it remains indeed indifferent whether the point of rest be near or far from the rock from which the stone was broken, whether it be at the bottom of the sea, or in the human hand that holds the stone, or on the firm surface of the earth; the stone will never of its own power return to the spot whence it came.

Quite different is the case with those living beings who, by an indwelling force and by their own power are removed from the place where they arose, and carried to far distances. The Salmon is born, far from the mouths of great streams and from the sea-coasts, in the fresh waters of brooks and rivulets, in the vicinity of their sources. There, when it issues from the egg, it finds for the first time the most appropriate element and the most fitting nourishment. When it becomes somewhat larger and stronger, it leaves this place of its birth, swims down the stream and goes to the sea-coast, and deeper into the sea after its prey,—which consists of other water-animals. But when the time approaches for it to bring forth, then in the midst of the nourishment that surrounds it, the longing for home leaves it no rest; the egg-laying females, in company with their partners, swim in schools up the rivers and their branches,

to introduce their brood into life on the same spot where they themselves first came from the egg. If you catch a female Salmon in the spot where it has spawned, and make a mark on one of its fins, you may convince yourself that instinct leads the fish back every year to the same place, and when you take the eggs, which the same fish has laid, out of the water and carry them in a vessel of water to another place in another river, in which Salmon have never been known, you lay the basis of a gradual population of Salmon in a new spot. For although fishes, as they increase in size, leave their birth place, and take up their usual residence at a great distance, yet, when they are ready to produce a new, young generation of their kind, they return every year back to the same spot where they themselves were young. And so is it known to be in regard to all fishes that, at the time of spawning, seek a certain region of the shore, that they yearly return to the same place, the place of their own nativity. In such cases certainly the wandering impulse toward home, appears to have a holding-point and guiding thread in the memory of the animal, for the old Salmon returns homeward by the same way he went forth. But even without such a leading thread, the destined goal is reached by that force which connects the two ends of life and brings its course back to the starting point. A sea tortoise was caught near the Island of Ascension, and brought on shipboard. On its under shell certain letters and ciphers were branded. The design was to carry it to Europe, but growing sick on the voyage and appearing nearly dead, it was thrown overboard in the British channel. Two years afterwards, the same tortoise, sound and well, was again caught in the neighborhood of the same island of Ascension. Led by the longing for home, it had made its way through the water a distance of more than eight hundred miles. Over as great or not inferior distances the journies of the bird of passage extend; and yet,

at the time of pairing, they all return whither they themselves were born, and, in the vicinity of the nest, in which they emerged from the egg, build their nests for their young.

Not merely from quite different lands and climes, but also from quite different elements, the out-running circle of animal life returns to its starting point. The horse-fly and the gnat come forth from the maternal egg in water, and in water the first period of their life is spent. Afterwards they become dwellers of the air, and enjoy the pleasure and freedom of a winged condition. Nevertheless, when she is to lay her eggs, the mother returns to the water; and so the female of the may-beetle forsakes the top of the high oak for the ground; and even the tree-frog leaves her green house in order to produce her young in the same place where she first saw the light—in the water. On the other hand, the helpless sea-tortoise, at the fit time, ventures out upon the land to lay its eggs in the sunny sand-bed, in which itself was born. The butterfly, who hovers, in its beautiful day, from flower to flower, and sucks their honey, seeks nevertheless, when its time comes, the unsightly nettle in order to lay its eggs on the leaves, from which it first drew its own nourishment.

In a somewhat changed form appears the attracting force, which chains the living to a certain abode, in the case of those mammalia which man has taken under his care and culture. Even among these it is indeed often the being accustomed to a certain feeding place or stall which draws them from far distances, or which makes the herds leap and low with joy when they return from their beautiful summer abode on the Alps to the neighborhood of their native village. Even the attractive society of their own brute companions works so powerfully that those goats, that have escaped from man and enjoyed for years the free life of the chamois, cannot resist the charm of old associates and the accustomed stall, when once again they hear

the tinkling of the bells worn by their former herd. In many other cases a deeper reason for this home-longing is to be discerned. It is not merely the crib, but the crib of *his master* which the generous steed longs for; and the faithful dog, escaped from confinement, hastens back, many days march, not only to the dwelling of his master, but to his master himself, to whose person he is bound by grateful love. Thus may that force, which among all living animals, leads them back to the parental home or to the places where, without parental help life received its first care, be related to those emotions, which, in the bosom of man, are fashioned to gratitude and love.

Even man himself, in many cases, is overpowered by a longing for the place of his birth, for the residence of his early childhood. He is, however, less bound by the force which connects him with an external home than any other living creature. Rather goes he, in obedience to his inclination, like the wandering dove, to such places of abode as best afford him the means of subsistence. But in his inner spiritual being he is truly at home only where those are whom he loves. Therefore, Jacob de Vries, in the midst of the earthly paradise of Cape Colony, felt a continual home-sickness for poor cold Greenland, because there he had enjoyed the love of human hearts, dearer and more precious to him than all the perfumes of the flowers, and all the deliciousness of the fruits of a warm beautiful land. Finally, from the case of human beings, whose true home and spiritual birth-place is not in the visible world, it is most clearly evident that the longing for home among all living creatures is the aspiration of gratitude, conscious or unconscious, to the origin and spring of life and all its joys. In the heart-sickening desire of home, which affects the wanderer from barren Lapland, as well as the Swiss, amidst the bustle of Paris, there mingles unmarked, with the longing for the holy peace which childhood possesses, the remembrance of the love

first enjoyed by man at his entrance into life, when he lay in his mother's arms.

> Our father's house, however poor,
> Nought on earth do we love more.

7. INSTINCT.

The word Instinct, Impulse, has been used from of old to designate particularly that disposition of the human mind, which results not from consideration and forethought, but from a higher suggestion; hence the ancients spoke not of an impulse merely, but of a divine impulse (*instinctus divinus.*)

An acquaintance of the celebrated French writer, Mad. Beaumont, desired to make an excursion upon the river with some friends. When all was ready, and he was about to enter the boat with the rest, his deaf and dumb sister came to him in anxious haste, and sought to hold him fast, seizing his arm and his garments, and when this did not move him to remain on shore, she threw herself at his feet, embraced his knees and gave him, by the most imploring gestures, to understand her entreaty that he would give up the excursion. The expression of pain in the looks and gestures of the deaf and dumb touched several persons in the company, and they begged the brother to yield to the wish of his poor sister, and relinquish the idea of going with them. Fortunately for him he complied, for the boat was upset, and several of the passengers were drowned; a lot, which would have befallen him likewise, as he could not swim, had he not been warned, as through a divine impulse, by his deaf and dumb sister.

That child of three years of age, that, at the siege of Vienna by the Turks in 1683, extinguished with earth a bomb, which had fallen into the city on a spot where it would have done much harm, also acted from such a divine impulse, for the safety of many.

A rich proprietor, once at a late hour of the night, felt himself urged to send various articles of food to a poor family in his neighborhood. "Why at this moment?" asked his people, "will there not be time enough in the morning?" "No," said the gentleman, "it must be done now." He knew not how urgently his benefaction was needed by the inmates of the poor hut. There, the father, the provider and nourisher, had suddenly fallen sick, the mother was feeble, the children had been crying in vain, since the day before, for bread, and the youngest was at the point of death; at once the distress was relieved. So also another gentleman, who, if I mistake not, dwelt in Silesia, felt himself impelled by an irresistible impulse to rise in the night and go down into his garden. He rose, went down, the inward impulse led him through the gate in his garden into the field, and here he was just in time to save a miner, who in ascending from the mine had slipt, and in falling had caught hold of the tub of coal which his son was drawing up by a windlass, but which, on account of its sudden increase of weight, he was no longer able to hold without assistance. A worthy clergyman in England felt himself also on a certain occasion urged late at night to visit a friend, suffering from melancholy, who dwelt at a considerable distance from him. Fatigued though he was with the labors of the day, yet he could not resist the impulse; he took the way to his friend and came upon him just as he was about to lay violent hands on himself; he was saved from this danger forever by the visit and consolatory words of his midnight guest.

Many such cases might be related, in which individuals by a sudden impulse have become the saviors of others, or even of their fatherland, like Arnold Winkelried, when at the battle of Sempach, with heroic resolution he caught the hostile spears, and pressed them down with his pierced body to the ground,

and so broke the firm ranks of the foe. But the good impulse does not always concern the welfare and rescue of another's life, but as often, and perhaps still oftener one's own life. So Professor Boehmer, in Marburg, once, when seated in a circle of friends, felt himself inwardly moved to go home and move away his bed from the place where it stood. When he had done this, he was able to return to the company, but at night while he was asleep the ceiling over that part of his room where his bed had previously stood fell down, and had it not been for the change, which an inward impulse had prompted, he would have been crushed.

How, in a case of imminent danger, one is prompted to seize a means of preservation, which is shown in the sequel to be the very best, many have experienced in themselves, and we shall hereafter mention some instances in point. And thus in the nature of man, phenomena are presented which are very similar to those suggestions and promptings of Instinct which guide animals in the choice of the means which serve for the support and preservation of their own lives, for the welfare of their young, and for the weal of the great whole, of which every individual animal is a part.

Besides, the animal cannot be guided in its action, like man, by intelligent consideration, and as little by experience, because it plays the part which Instinct assigns it, immediately upon its entrance into life with perfect promptitude. A chicken, which had been hatched, not by a mother, but in a little artificial brooding-oven, descried, just as it had broken out from the shell of the egg, a spider, which it sprang at and seized as skilfully as if it had been long practised in the art of catching insects. When the young of the sea-tortoise in the bed of sand, which is their birth-place, have crawled out of the egg, they hasten immediately in a straight line to the sea. You may turn them from this course any way you please, you may

obstruct their way with stones and sand-hills, which cut off their path, still they will always turn straight towards the sea. On the other hand, the young of the land-crab, which first come out of the egg under water, soon after their birth make for the land, and there seek out for themselves the situation best adapted to their subsistence. Scarcely has the ant crawled out of its chrysalis, or pupa-state, (commonly called the ant-egg) when, if it is of the sex of the workers, it immediately joins its elder associates in the business of gathering and carrying food for the helpless little larvæ of the community, and assists with all diligence in the work of building, as well as in transferring hither and thither the pupæ and the eggs. And it is not, as might be thought, only a blind imitation of the activity of the rest, which leads the novice on the path of his natural destination, for when the new-born ant is not of the sex of the workers, but is a male, or one of the more perfect females, then it does not permit itself to be hurried away by the busy stream, it goes directly the way of its own calling, through the troops of the rest, out into the open space, where it rises into the air on the tender wings which are furnished to the males and the perfect females for the purposes of swarming.

That it is not the imitation of the instinctive actions of others of the same species, which directs each individual to its own mode of proceeding, is evident in every way. Nightingales and thrushes, which have been taken from the nest young, and reared far from their species, when they are let loose in the spring, build just such nests for their young as other birds of the same kinds. A beaver, which had been taken from its parents before its eyes were open, and which had been supported by a woman's milk, until it was large enough to take the usual food of its race, arranged the broken twigs, from which it had eaten the bark, in a corner of its cage, one over the other, and when some earth was given it, it formed it with its

tion. The troops of dancers with their partners, that a little while previously were seen, on many a plain near the sea-coast ascending like clouds or pillars of smoke, now sink down to the earth, the males die, or become with many thousands of the troop, a prey to insect-devouring animals, but the surviving females, as if they were ashamed of their mad merry-makings, crawl away to some ant hive of their own species. Whether it be the one in which they were born and brought up, or another, they now bear, in the hope of a new race which they bring with them, the insignia of a majesty and royal authority, revered by all beings of their kind, and received with loving homage; every where, in such a place, they are sure of a cordial reception and liberal support. But the tender, finely-woven wings, in the possession of which a little while before, the highest joy of life consisted, have now become, at the present stage in the little creatures destination, instead of a delight, a burthen. The monitions of instinct teach her this, and by her own efforts and limbs she tears the brilliant ornament from her back, and creeps wingless, in among the class of unwinged workers, never again to leave them in the hive.

The beautiful fiction, not without meaning, that the pelican, in the ardour of its love for its young, in order to save them from death, tears open its own breast, and feeds and re-animates its fainting brood with its own blood, is indeed not to be taken to the letter, for the blood, with which the white breast-feathers of this bird are sometimes seen to be sprinkled, when it is feeding its young with the fish which it brings in its pouch, comes from the wounded fish, or, if in rare cases, it is its own blood, from the slight wounds which the young pelicans make with their sharp beaks in the pouch of their parent, into which, while they are yet young, they reach as into a dish. But for the rest it is no fiction, but experience daily shows, that maternal affection in the animal world is stronger than the necessities

of the body and the pain of death. That it is not, so to say, a relationship of bodily elements, of flesh and blood, perhaps, which subsists between the mother and the young, born of her, but the impulse, the instinct of a love, coming from another and higher source, which gives its force to maternal affection, we are taught by the tenderness of animals towards those helpless little ones which a higher, a divine Providence has committed to their charge. Between the wag-tail and the poor little motherless cuckoo, which came in the egg into her nest and under her wings, there is no flesh and blood relationship; nevertheless the tender foster mother wearies herself almost to death in seeking to satisfy her hungry foster child. A celebrated naturalist, (Bechstein) once saw, in the autumn, when it was so late in the season that there was frost and even ice o' nights, a wag-tail at a sunny brook, running and flying to and fro with great diligence. Whoever knows how irresistibly the migratory impulse seizes this bird, when the time is come when all its tribe departs, and when, at the approach of winter, its food begins to fail, he will perceive that there was something unusual in the prolonged tarry with us, of a bird that lives upon insects, far into October, when in the open air scarcely a solitary fly is to be seen. Accordingly, it appeared singular to the above mentioned observer, and he followed the little animal as it bore away an insect in its beak, as if it were foraging for its young. He saw from the opening in a hollow tree, the head of a tolerably large bird extended eagerly to seize the food which its foster parent brought. It was a young cuckoo, whose real mother had by some means deposited its egg in the wag-tail's nest in the tree. The young bird had grown, had become completely fledged on the head and neck, but at the same time had become a prisoner, for the opening was too small to let his body through. But the tender foster mother would rather have died with her nursling than forsaken it in its need.

What maternal care and fidelity can exceed that which the working classes of bees and ants show towards the eggs and the young of their queens; what patience of a human instructor can exceed that which the female turkey exercises towards the chickens of a strange family, which she has been made to hatch. In the great Nursery of Nature, those creatures are not to be pitied, which, in our eyes, seem the most helpless and forsaken, for it is precisely these which are cared for the most generously and tenderly.

In a quite otherwise remarkable form does instinct appear, as the impulse and instrument of an all upholding Providence, when the object sought is not the welfare of individuals or families, but the well-being of living creatures collectively. The force, which then moves the animal world, stands in so opposite and contradictory a relation to the instinct of self-preservation, that it often leads myriads of individuals, for the welfare of a whole country, to their own sure destruction. All the powers of men and of those animals which come to the aid of man, in keeping down the multiplication of the white cabbage-butterfly, so destructive to our vegetable gardens, are often insufficient; if the increase went on without interruption, our cabbage crop would be utterly annihilated. For this mischief, however, Nature has her powerful remedies. Whole clouds of those butterflies, which produce this destructive caterpillar may be seen quitting, all at once, the region of which they were the plague, and taking a course which, for the most part, terminates in the ocean. Such a caravan, giving itself to the fishes for food, continued, according to the observations of Lindley, several days, and kept its direction unchanged toward the sea. Kalm saw butterflies of this description over the waters of the British channel. The swarms of locusts, when their number have grown formidable, take at last their way towards the sea or the desert, and the same has been remarked

of other kinds of injurious insects. The lemings too, the field-mice of the high north, when they have become too numerous for their home, collect in immense flocks and move in a straight line, often towards an arm of the sea or to rivers, in which they find their grave. Even in the most favorable circumstances, only a very small portion of these emigrants return home. As a living body, in the growth of its limbs, sets, by its own, inward power, certain limits to itself; so is this done also by the animated whole, by means of the force of instinct, inspiring its members. The water of a fountain rises, through the pressure of a higher column of water, to a certain point, but when the agency of this pressure ceases, it tumbles ceaselessly down to the ground.

The force, which as instinct connects individuals in relations of mutual service, and with them, tends to the weal of the whole, not only controls the individual parts of the external world, but shows itself active also in the interior of every animated body, fashioning every element and organ of the same to the collective purpose of its life. As every part serves all other parts, so all at last help the activity of the animating soul.

The same thing which instinct achieves in obvious ways in regard to beings of external nature, is accomplished by the forming principle in its more hidden and inner circle. The bird must build a nest for the eggs which she is to hatch; a nest, the more carefully made, the more tender the situation of the young is, who come forth from her eggs. As the young of the singing bird come blind and unfledged into the world, the old birds must obtain for them such nourishment as is best adapted to their first stage of life, and in this case, a remarkable delicacy of instinct developes itself in birds fed from the beak, as the food which the parent birds bring to their new born young is different from that which they provide several

days after, and this again differs from that which they procure for them at a more advanced period. All these obvious expressions of a building instinct, and of the instinct of maternal love disappear in the case of the quadrupeds; an animal of this class needs not the arrangement of a nest for the hatching of eggs, for its young become ready for birth, not without, but within, its own body; it requires no instinct to lead it to seek their first nourishment for its young, for that nourishment without its own outwardly visible aid is prepared, as mother's milk, in the vessels of its own body.

But on the other hand, man, highly endowed as he is, must, through the thoughtful industry of his hands, provide himself clothing for his body, which shall cover him only lightly in the hot season of the year, and protect him from the cold in winter, while the plumage of the goose and the duck, as well as the fur of many quadrupeds, takes an increased thickness at the approach of winter, which in spring is exchanged for a lighter natural garment. What dress of man, prepared of the choicest stuffs and fashioned with the highest art, can compare in beauty and splendour with the plumage in which many birds, sparkling in all the colors of jewels, appear at the time of their nuptials, and how poor, besides, would man's winter wardrobe especially look, if for the fabrication and decoration of his garments he could not avail himself of the wool and fine furs with which the forming power of Nature furnishes animals without their co-operation. Man must take great pains to form the weapons he uses in war, or to prepare the tools with which wood and stone are wrought; the weapons of the stag grow out of his own body, and so is it with the woodsawing wasp and the shell-fish, which, with its file-shaped mouth, works its way into the rock. That which is accomplished in man and in the animal, in the former by understanding, and in the latter by instinct, in ways outwardly perceptible, enters still more fully into the hidden,

inner circle of forming and fashioning forces in the plant. The plant needs no artificial arrangement of storerooms, no gathering of food for the seed or the germ which it leaves behind it when it dies, but to the grain of wheat and the eye of the potato is furnished from its first formation an abundance of nourishment that fully suffices for the development of the germ.

Here the agencies of instinct, which manifest themselves among animals in an impulse to wander forth for food, and to annual migrations, and in the art of preparing their abodes, are transferred to the inner parts and elements of the individual plant or animal body, without suffering any change of their nature and purpose. For when every substance which the animal takes for food, so soon as it enters into the circle of its life, finds its way through all the regions of the body to its destined place; the lime to the bones, the silica to the hair, the iron to the blood, the sulphur and phosphorus to the brain and nerves, and thence to the bones—shall it be less wonderful than the migrations of the swiftly and lightly moving bird to the place of its birth and its food? When whole masses of material elements that have become worthless, press toward the surface of the body in order to escape by the perspiration of the skin, and to lose themselves in the ocean of air, is it not the same impulse which collects so many hurtful insects (see p. 33) to whole clouds, and guides them off into the sea, so that the land may be freed from the burthen of their excess? We admire the generous excitement which is communicated to an ant-hill or a beehive the instant any external force has broken into it, or when any danger threatens the same from internal enemies. But when, upon a limb's being wounded, or a bone broken in the body of an animal, all the forces and fluids of the same instantly in flaming haste unite to heal the wound or the fracture; and when this endeavor is successful, when in the diseased state of the body, the storm of a fever is raised, which,

when it is powerful enough, decomposes and drives away the morbid particles—shall this, in a less degree, command our admiration? The spider prepares ingenious nets to catch the prey, which serves it for food; is the structure of the several secretive organs, which fashion themselves in the body, in order to produce bile in the liver, and bone in the membrane of the bones, out of the elements which have been introduced through the blood—is not this structure as ingenious, and are the fine webs and formations of which the animal body is made, and which are perpetually renovated, inferior to the web of the spider or to the buildings of the bee or the beaver?

Every where, as we have seen in the foregoing chapter, (6.) instinct is the agency of that creative power, by which all visible beings are adjusted to one another, like the parts of a house or a temple by an intelligent master builder and his subordinate laborers. Every living being is, in the ranks of these laborers, employed in the construction of the whole. The solitary workman who places the top-stones on the pinnacle, and fastens them there with mortar, attends only to this work of his hands, he heeds not what the hod-carriers are doing below as they prepare the materials, which come from the earth, the stones and the mortar, and carry them up to the laborer who is helping to complete the great structure. Only the master-builder, to whom the care of the whole is devolved, goes with his all-ordering eye, to the humblest laborer below, who is digging out and preparing the materials of the edifice, and adjusts the labor of all the workmen, of those who carry the brick and stones, as well as of those who are at work at the top, to the general plan of the whole.

When the morsel of nourishment, or the refreshing draught has entered the mouth and passed into the stomach, then we take no heed how, out of the same, the gastric juice and the blood is prepared, nor how by the breath from the

blood the animating flame is kindled and kept alive upon the altar of life; we remark nothing of the formations and dissolutions of single parts, which take place in our bodies. The working of the soul in the body and on all the elements of the same, resembles a mighty motion, which carries along with it in its own direction, every thing moveable that comes into its vicinity. The beam of the sun, wherever it reaches, can only illuminate and warm, the flame of fire can and must produce in every thing combustible, which it touches, only a similar flame. So in the soul's life, which is a working and moving towards a certain aim, dwells a power of making every thing which comes within its sphere, help to the accomplishment of its end, and in its career, carrying it along with it to the appointed goal.

The blowing of the wind carries all light bodies with it in its own direction. When an eagle, ascending from the ground, excites this motion of the air by the powerful force of its wings, the light dust, which lies on the ground, whirls away after him, but the eagle, who has in his eye only the aim of his flight, observes it not, for the dust is external to him and below him. So, too, the animating principle of the animal and of the plant imparts the direction of its own life to the material substances which it forms into a body, to be the instrument of its activity, and sets in motion for its service. The material is brought to it from without, and handed to it, for the advancement of the grand edifice of the whole, from a depth which its eye cannot fathom. But He, whose work both the material is, and its preparation, by whose act and whose will the same material is transmitted from hand to hand, until we behold it upon the visible pinnacle of the building, sees and knows the whole method of the plan, already pre-arranged in his mind.

8. THE COMPASS.

The first man who made the discovery that there is an iron stone—the magnet, which attracts other iron, may have wondered not a little at this quality in an unsightly stone. As the animal seizes the food, so the magnet seizes the iron, but it does not consume it, it converts it into its like, for if a steel needle (a common sewing needle,) remains for a space of time in union with the magnet, then after it is withdrawn, it is not only attracted more powerfully by the magnet, but it now also attracts other needles or small particles of iron. With an iron needle, thus become magnetic, the experiment was probably made in the first instance merely by way of amusement, by letting it float, like our little artificial magnetic fishes, in a dish of water on a little chip of wood or cork, or by suspending it by a thread, in order the more easily to observe the readiness with which it followed the magnet. In this case it must have been remarked that the magnetic needle with its two ends constantly stood when at rest in the same direction. In some way of this sort, the compass was invented, which, in its earliest form, was a simple magnetic needle, suspended by a thread or floating upon some light substance in water, which, by its constant position, north and south, even under the cloudiest skies, pointed out the situation of countries, and thus, especially when a better and more convenient form was given to it, became a sure guide to travelers by land and sea.

When the migratory bird, or when other animals are led by the ruling force of Nature, out of their previous sphere of life far over land and sea to a distant goal, they indeed have no need of our compass; but when we, with our inquiring reason, wish to follow the instinct of the animal upon its dim and circuitous paths, then the knowledge of the nature of the compass comes to our aid.

The quarters to which the freely moving magnetic needle turns of itself, are in general the regions of the earth's poles, the north and the south; each of the two ends of the needle represents in little a pole of our globe, and is attracted in its motion towards the pole which befriends it. The property on which that motion rests is called polarity. When two such needles or two magnets of equal strength are brought near to each other, it is observable that those ends which in both are turned towards the north or the south do not mutually attract but repel each other, the north pole of the one attracting the south pole of the other, and the reverse. So that it may be said that each pole of a body of equal polaric properties attracts not that which it is itself, but rather that which it is not.

When we now further ask, on what is all polarity in nature based, the answer is briefly this: On the presence of a Creator in opposition to his creations; upon the continuous energy of a creating and upholding divine power, in the whole creation.

The Creator has placed in every one of his creatures, in the mighty stars of heaven and in the grain of sand, in the spirit of man and in the forming life of the smallest moss, a certain measure of his own power, a creative force and energy, by which the individual being exists and continues. This indwelling derived power it is, which, as we saw in the preceding chapter, repeats, in every living body, a work of creation in little, inasmuch as it unites the single elements and parts to a well-ordered whole. As the magnet communicates its magnetic property or polarity to every atom of iron which it attracts, the same is done by the creative power of the soul of things to the substances which it draws within the sphere of its activity; each of these receives a certain measure of creative power; it becomes polaric. For polarity consists in this, that a thing, by virtue of its implanted power, can place itself

to another thing in the relation of the moving to the moved, like the Creator to his creations, while again it can take to yet another thing, a subordinate position, that of a moved to its mover.

The activity of that polarity which is called forth in all parts, in every drop of blood and in every fibre, from the life of the same, is just that we have described above (p. 35,) as the business of the carrier working from below upwards. The beginning and the continuance of all their living action and motion, in all souls, comes from the power of the Creator himself, and this it is, whose all-considering foresight appoints to the impulse or instinct, that takes its origin from the all-embracing power, its sure path. The north pole of the earth, or that magnetic efficacy which comes from the depths of the planet, is far removed from the needle of our compass, and yet the impulse of motion towards the pole always finds again its right direction, whatever external powerful influence may endeavor to interrupt it; the same thing takes place in reference to the impulse of instinct, which has its origin from a power, before whose might the distances of space and of time are as nothing.

Thus the compass, with which the seaman ventures boldly upon the great deep, gives us, in its little measure, an image not only of our globe and its polarity, but also of the general arrangement of all the being and life of the created world. As the creation only is and continues through the influence of a forming, ordering and upholding Creator, so every single thing is and continues only through the creative power which dwells in its being, and every one thing represents in itself the opposition between a creating and a created; every one of the myriads of beings is a compass, whose beginning and end continually point each to one and the same point. But this

one right point, to which all the being and life of things turns, is God, who has made us and all things, and works through all with his almighty word.

9. THE IMPULSE OF THE MIND TO WANDER FORTH.

The companions of the great Columbus were not to be blamed when, upon their bold voyage in the midst of the Atlantic ocean, just where it is the broadest, they gave themselves to anxiety and fear. Their confidence and their hopes went not much beyond what their eyes saw; their thoughts and imaginings were not directed to the achievement of a bold deed, to the attainment of a high intellectual aim, but to a speedy acquisition of riches, to sensual enjoyment, to bodily well-being. The eastern shores of India, the land of gold, they hoped to reach, there to enrich themselves with pearls and precious stones, to revel for a time amid the fruits and natural gifts of the land, and then to return home and enjoy in peace their treasures. But now when they saw themselves in their crazy vessels in the midst of the sea, when the trade wind from the east caught their sails and so hastened their voyage over the boundless expanse of waters towards the west, that they would soon be many hundreds of leagues from their country, when the hope of land, which the appearance of sea birds and single strips of green sea-weed had excited, still remained unfulfilled, and more than a month passed and the wished for land appeared not, their confidence was so prostrated they thought only of returning, and only the unshaken firmness of their leader could suppress the outbreak of open mutiny.

Here the flesh rose against the spirit, for while his companions saw only with the eyes of the flesh, and trusted and hoped only with the heart of flesh, the great Columbus, with the eye of the spirit, descried far over the waters the goal of

the voyage, which was hidden from the others. He had a surer guide than the compass, the strong trust of a pious heart in God's favor and help, in an enterprize, which was destined to attest the irresistible impulse of the human mind to investigate the unknown, and to spread the light from the east over the darkness of the western hemisphere. That which filled his associates with dread, the speed with which, by winds and waves, the voyage was extended over more than nine hundred miles—that inspired him with joy and strengthened his spirit; for his thoughts were not backward but forward, hence the favorable wind led him on like a messenger from Heaven; his firm hope rested already on the land which his eye had never seen and from which no tidings had yet reached him or his companions.

The flocks of swallows pass from the north-western coast of Europe, almost by the same broad path over the sea, and not one of them on this great journey is seized with despair, not one is disposed to turn back, because in all a true force rules which fastens its guiding thread at one end to the distant, as yet unreached goal, and holds it there as strongly as to the home just forsaken to which the other end is bound. The force of instinct everywhere appears as a search which is led astray by no obstruction, because that towards which the outward nature of the animal moves, has already become in its inner nature an object of enjoyment, akin, according to its measure, to the enjoyment with which hope inspires us human beings.

There is a migratory impulse of a much higher and mightier kind than that which leads the bird over the ocean or the insect from one element and sphere of life into another, an impulse which leads the soul that it moves, not only from one end of the earth to another, but above the moon and stars, beyond the boundaries of the visible immensity into an invisi-

ble world of the spiritual and eternal. This migratory impulse dwells in the spirit of man, it is an impulse toward an orderly knowledge, an understanding of the connection of visible things with one another, and especially of their meaning in relation to us; an impulse towards the investigation of the invisible origin and end of our own being, towards acquaintance with other human minds, as well as an inward longing after spiritual association with them in the way of wisdom and knowledge. At the foundation of this moving force rests a hope, stronger than that which animated Columbus on his voyage, a hope that extends beyond the grave into an eternal life, and whose anchor rests on a ground which remains firm amidst all storms.

To the force of animal instinct the bodily limbs are given as its tools; the migratory bird has his quick-moving wings; the diligent bee those basket-shaped additions to its feet in which the blossom-dust is collected and carried; the beaver his chisel-like teeth for the cutting of the trunks and branches of trees, and his trowel-formed tail; the spider the glands from which the viscous fluid comes, which hardens in the air to a thread. Instinct stirs itself oftentimes before the bodily implements through which it afterwards announces itself are fully fashioned; the young goat tries to butt ere he has horns; a little crocodile, just from the egg, instantly endeavored, in fore-feeling of its future strength, to bite a stick which was held to it. The soul besides precedes the body, and the latter becomes only gradually subjected to the efforts of the former; on this account even instinct awakes before it is fully furnished with the means of expressing itself.

In general the peculiar privileges which animals have over plants, namely, the faculty of sensuous perception and voluntary motion, depends upon the possession of organs of sense, and above all of sight and hearing, as well as moving muscles; the farther the eye of an animal sees, the farther it can move,

as a general rule; the greater the strength of its limbs and the command it has over them, the more decisive is its destination to overpower other animals, and to feed itself on their flesh.

In man all the organs of sense are fashioned in such proportion, the limbs are so perfectly moveable, that his body becomes thereby a most perfect instrument of the all-investigating spirit and the intelligent will. His eye beholds all the beauties of the Creation, whose harmonious sounds his ear perceives; his hand, with its cunningly working fingers, imitates everything which his eye beholds, and gives to a dead instrument a power of tone, by which it rivals all the melodies of birds, and the human voice itself. To the inward impulse of human nature towards a knowledge of the works of God, and to an exercise of its powers in harmony with the divine order of the world, is united a body, with all its limbs and powers perfectly corresponding. Nevertheless we can here plainly perceive that the inner spiritual power, with its impulses towards intelligent understanding and activity, comes not from the perishable body and the arrangement of its parts, but that this power belongs to the spirit and is one with its essence. For this reason it exists, and the impulses dwelling therein manifest themselves, even when the condition of the body is unfavorable to its activity, and in a high degree obstructive; and we may thereby see that the spirit will continue, when the body is no more, even as it is active before the body exists. We will endeavor to illustrate this by an example.

In Hanover, in the State of New Hampshire, (U. S. A.,) in the year 1829, was born *Laura Bridgman*, the daughter of respectable parents, whose case shows, as in many instances of the blind, that the human spirit remains the same in its powers and indications even when the avenues of external knowledge, the higher senses, are entirely closed to it. Until she was twenty months old, Laura seemed to be on the brink

of the grave, for almost from her birth, she suffered from violent convulsions, and was, in all respects, very feeble. Not until she was twenty-one months old did she gain any strength; before the end of her second year she had learned to speak some words. But this apparent bodily improvement was only the commencement of still greater suffering. The internal disease, which previously affecting the very springs of life, had produced those dangerous convulsions, ceased to affect the brain, and fell upon the organs of sight and of hearing, which where wholly destroyed; the life of the child was saved, but Laura was from that time entirely blind and deaf, and, as it afterwards appeared, deprived also of the sense of smell and of taste, for it was found that she was unable to distinguish rhubarb from tea. The poor child's life was preserved that she might teach others that there is in them another being and life than that of this changing perishable flesh.

During her last severe illness and for a short time afterwards, Laura still spoke some of the words she had learned, but as she no longer heard her own voice, she soon became entirely dumb. She gained strength slowly, and only at the beginning of her fifth year was she, apart from the loss of her senses, to be called perfectly well. But scarcely had she attained to health, when the mind of the child, inwardly richly endowed, but outwardly so impoverished, announced itself, with all its inborn powers and efforts, in a manner as evident as if nothing had happened that could injure it from without. Immediately there appeared, in the same strength as in intelligent children with sound organs of sense, the instinct toward knowledge, and the same curiosity. Laura began to run eagerly about the house and to examine all objects with her hands. In particular she followed her mother at every step, endeavored with her hands to understand what her mother was doing when the latter was busy, carefully imitated her, and in this way learned

several female employments. Like other girls of her age, she understood how to play with dolls and other objects of childish amusement; but her delight was the greatest when she had learned any thing new, or discovered the use of any object, or the purpose of any labor.

In the commencement of her ninth year, (1837,) Laura went to Boston, to the Blind Institution, under the care of its excellent principal, Dr. Howe. When the child felt herself at once separated from her most devoted and dearest friend and nurse, among strangers, and in a strange place, she was for a time timid and embarrassed, but it was manifest even in these circumstances that the deepest, inmost impulse of our being, existing in the very essence of the mind, is mightier than the longings of our bodily nature. The craving to know and to inquire, found in its new surroundings, increased nourishment; the thirst for spiritual fellowship was much more abundantly met than in the paternal home; the little creature, therefore, was soon as happy, or even happier in her new abode than at home. When the lively, intelligent child, as gentle and caressing as a lamb, was approached by all the inmates of the Institution with love, and when her blind foster-sisters played with her, when even Dr. Howe, on one occasion, played with her, and made believe that her doll was sick, and that he was its nurse, feeling its pulse, and laying a plaster on its wooden head, then she laughed and leaped for joy.

The child, so much pitied by others, nevertheless how happy was she in herself, how cheerful and serene! She knew that she was destitute of what others possessed, but at the same time she felt that she still possessed what is more than the outward senses, and which put her on a level with all others; she was happy in the activity of an inquiring mind, and in the love of other human beings. She soon became so well acquainted with her new residence, that she ran up and down stairs like a

seeing child, and distinguished all the forty inmates of the house by the touch. At table, as on every other occasion, she bore herself with a propriety, which was not learned from seeing the example of others, but which came from within; she dressed and undressed herself without assistance, and manifested, in the braiding of her hair, the love, peculiar to her sex, of neatness and ornament; in the female employments of embroidery, knitting and sewing, she showed as much industry and skill as her companions who, though blind, could yet hear. Thus was she in the most favorable element for the development of the impulses of our interior nature, and it suited her well.

But in the midst of intellectual excitements, the germs of natural love and grateful dependence towards her first protector, her mother, were not destroyed, but they grew with her spiritual development, and became ever more powerful and more elevated. About six months after Laura's entrance into the Blind Institution, she received a visit from her mother. The little deaf, dumb and blind girl's recollection of persons had been overlaid with so many new impressions that she did not recognise her mother in her probably strange clothes, although she felt inquiringly of her hands and dress. She soon turned away as from a stranger, and even resisted the caresses of her mother, although a well known string of beads, which the child had worn at home, and which her mother had brought with her, gave her great pleasure, and she intimated to Dr. Howe, when she received them, that they came from her home. The mother next put into her hands another well known object from the paternal dwelling. Laura was greatly moved, examined her mother more closely, and gave Dr. Howe to understand that the lady certainly come from Hanover, permitted herself to be caressed by the stranger, and then again went away from her. Her mother, painfully affected, again approached her, and then all at once the force of filial love

awoke with all its recollections; she felt very eagerly the hands of the supposed stranger, soon became pale and then red, and when her mother drew her to her, all doubt vanished, she threw herself with the liveliest expressions of delight in the arms of her mother, and left her no more; neither of her playthings nor of her playmates did she take any further notice.

The spiritual life, struggling within her to unfold itself, showed itself most decisively in relation to the maternal visit. When her mother was about to leave her again, the child accompanied her to the door, holding her fast, felt round with her free hand to ascertain whether any one were near, and when she discovered that one of her best loved teachers was present, she seized her hand, once more pressed her mother close to her heart, then let her go, and threw herself sobbing into the arms of the teacher.

That, as we have said, those natural affections which belong rather to the animal nature, were by no means weakened by the growth of the higher faculties, but only elevated, and by the spiritual element which they received, only rendered the more strong, became most strikingly evident in Laura, when she had learned to express herself, not indeed by sounds, but by signs addressed to the sense of touch, in a language of the thoughts made perceptible in written letters. With the gift of language grew also the power of distinctly recollecting persons and things of the external world; the expression of love and aversion became better defined. So soon as she had learned to form words with her fingers, her mother and her desire for her, became a more frequent subject of conversation; her first letter was written to her mother; and when by chance the female teacher whom she loved, caressed any one of the other children, which perhaps stirred a little jealousy in the blind child's heart, desiring Laura, then her little fingers would say, poor, love-[illegible]r no[illegible]r will love me."

"My mo[illegible]the

In aid of the instinct, by which the animal is guided, come the peculiar forms of those bodily members by which the inward impulse is able to express itself; this impulse fashions its appropriate organs. The instinct which leads the animal to its food, is served, in the bird that lives on flesh, by the swift wings with which it rushes on its prey, by the feet with talons, as well as by the beak for seizing and rending its food, and by the stomach and intestines in which the food is dissolved, and the vessels in which it is further prepared to nourish the various parts. Also the spiritual impulse in man towards what is to be known, and to the fashioning of the same into an inner form of intelligent understanding, and making it the means of rational action, forms for itself its peculiar organ, *language*, the words of which are first an inward, super-sensuous element, and then are transformed into external and perceptible signs. The flight of the eagle, when it rushes on its prey, or of the swallow, when it traverses the ocean, is swift; but the language of human thought is incomparably swifter, for scarcely is the word thought or uttered, when the discerning spirit, upon the pinions of language, has reached the object, of which the word is the sign; we are in spirit with a friend, whom we name, or in the places once visited and seen by us, although bodily we may be in a distant region of the earth. With the thought and the utterance of the word, the human spirit possesses at the same time the power of transforming what has been seen and felt bodily, into a being of a spiritual essence, which, as such, becomes its inalienable property, as imperishable as the spirit itself is.

If the moment that a bee comes forth in its perfect winged form into the light, it is placed under a glass, supplied abundantly with its means of nourishment, it cannot rest, but flies anxiously to and fro in its prison, and as soon as it is let out, it immediately uses its wings and other limbs in searching and

collecting materials and in the construction of the nursery, which, with the other bees of the swarm, it prepares for the young brood. The innate force of the human spirit likewise, like a higher kind of mechanical instinct, prompts man, without delay, to aid in the structure of a fabric, whose completion is the common work of all human beings,—the construction of a language or speech intelligible to every individual. This is the mighty edifice, in which long-gone generations have already laid up for us the materials of thought and knowledge, and to which we also commit fruitful seed for the coming time.

The living power, which rules in the nature of the bee, cannot but exert itself; it must manifest itself in the formation of the wings and other parts of the insect, which the governing impulse toward gathering and building requires for its service. So also the rationally discerning and willing mind of man cannot do otherwise; it must form for itself a language for thought, and by means thereof, comprehend the world of knowledge, standing open before it, and by the communication of its thoughts to other human beings, work together with them in constructing the common fabric of knowledge. The soul of our poor deaf, dumb and blind girl, resembled in its bodily limitations, through the want of the higher organs of sense, that bee, which at its first coming forth from the pupa state, is kept confined under a glass; this human spirit struggled eagerly to escape into the sphere of that free action, where it could obtain a language for its thoughts, so that it might receive knowledge from without, and communicate its own emotions to others.

When the human soul begins the work of forming an instrument for itself, partly spiritual and partly material, as this of language is, it follows, first of all, the course which the breath of the body takes. As breathing is an inhaling and exhaling of the vital element of the air, so speech establishes a receiving and giving out of the elements of knowledge. The impulse to

speak, as essentially implanted in the mind as the impulse to breathe in the body, makes, on this account, common cause with its physical companion and copy: it avails itself of the voice to satisfy itself. Even the born deaf, who has never heard the human voice, feels himself prompted involuntarily to express his sensations and ideas by sounds. An individual born dumb, who had been so far taught that he could make his thoughts known by words, said of himself that, before he had learned words, he had always been impelled, in addition to the gestures, by which he wished to distinguish individual objects, to use his voice, and that, for every person that he knew, he had indeed, at first, had a certain utterance of the voice, or, as it were, a name, intelligible only to himself.

In the case of the blind Laura, this necessary connection between the emotions, and ideas of the mind, and the voice, was observable in quite singular ways. When she entered a room, in which were a number of her blind companions, she embraced every individual, giving at each greeting a peculiar sound, which the blind children, more attentive and practised than the seeing, learned to distinguish as readily as an articulate name. Even when she was alone and thinking of some one of her friends, whom she especially loved, she uttered an inarticulate sound, by which that friend was designated; and when she was asked why she did not express the name of a person she was thinking of, as well as the names of the objects of which she thought, by the finger-alphabet, she answered, "I do not think of printing her name, — —, because I am thinking how much she loves me and how much I love her."

The human being who possesses in the lowest degree, the capacity of speech, the uninstructed deaf and dumb, for instance, is like the bird or other animals endowed with voice, that seek to express the feelings of bodily pleasure or pain, of

love or dislike, of anger or terror, by tones of the voice; and even afterwards, after instruction, the organ of the voice, at every lively emotion of the spirit, seeks to represent the truth, and be the herald of the affections.

In the case of the deaf and dumb, and even of the blind, the impulse of the human soul to speak, makes way for itself in another direction, through the language of gestures, which is just as instinctive as the movement of the hand towards the object which one wishes to clutch. Many birds, as the common starling, accompany the tones of their song with measured movements of the wings; some kinds of cranes are even moved, when they hear music in the neighborhood of their cages, to dancing motions of their feet and wings. Such human beings as are outwardly defective, not only the dumb but the blind also, can imitate no gestures which seeing persons make before them; they cannot learn their language of signs from others, and yet they invent for themselves a language of this sort, perfectly adequate to all their wants. A blind person of Ostend, Anna Zimmermanns, was able to express herself so intelligibly by her language of gestures that every seeing child understood her, and she was employed to make little purchases out of the house. Another, who had been blind from his birth, like Anna Zimmermanns, the Scotchman, James Mitchell, was able to relate little stories from the narrow circle of his experience, by the language of signs. Laura, too, conversed with persons, who were ignorant of the finger alphabet, very fluently by gestures, and when strangers were introduced to her, her first question usually was, whether they were blind or could see, so that she might choose her method of communication accordingly. Besides, the countenance of this lively child expressed, in the most striking manner, all her inward emotions, hope and fear, pleasure and pain, self-satisfaction and penitence.

Although, however, even in the deaf and dumb and the blind, the discerning spirit is not destitute of the innate impulse, which prompts to the formation of speech, but manifests the same in a powerful manner, it happens with it in these cases, before a knowledge of words is obtained, as with a stray bee or the wasp, which is taken from its swarm, and put into confinement, where every thing else is provided for its life and activity. So long as the insect is vigorous, instinct shows itself still in the same way in which it acts in the swarm and the hive, but yet only very rudely; the little drops of honey are formed without object, scattered here and there; the wasp gnaws, indeed, the rotten wood, and works up its fibres to a substance resembling blotting-paper, but there comes no complete work from his labor. In language, which man, in common with his fellow men, has received from the primeval times of his race, as a common inheritance, there reigns a spirit of universal, intelligent knowledge, which acts upon all human beings with an influence as animating and controlling as the power of the queen bee over all the bees of the hive. With language, a light rises upon the darkness of human nature, which illuminates the whole external as well as the internal kingdom of creation. The wanderer who at night sees only a solitary tree or rock near him, beholds at once, when the day breaks upon him, the whole landscape with its woods, mountains and rivers; he discerns its single parts as a harmonious whole, and feels himself now attracted and strengthened to join cheerfully in the common labors of humanity. So is it with the deaf and dumb, when he passes from the narrow circle of the language of signs, into the wide sphere of the language of words; and yet more striking than to him must be the benefits which the language of words bestows upon the deaf and blind.

We possess various accounts of deaf and dumb persons, who have learned to express themselves in written language, and,

ing to the object, *book*, *bread*, *leaf*, and which have been placed under his fingers, but this employment appears to him a mere play, the use of which he does not understand, and which perhaps soon becomes irksome, as was the case with James Mitchell, whose education was not begun until his nineteenth year.

This danger did not befall the intelligent little Laura. When for the first time she placed the written word *key*, not along side the key, which had been previously used, but by another, never before used, and taken from the door, then a delighted expression of self-content appeared on her countenance; the meaning and purpose of written signs as a means of understanding the thoughts of others, and of communicating one's thoughts, was now made clear to her; a reflection of human intelligence beamed from her features.

That, which comes forth wholly from the spirit, always appears to the bodily eye as a miracle, for it starts forth at once and stands perfect before us there, without our observing the hidden source from which it came; its goes its way in many-sided activity through the material world without our seeing whither. Such a daily miracle, repeated before every sound human child, is the apparition of human speech out of the single elements which the spirit receives from without. Who would undertake to teach grammar, and the combination of single words into intelligent speech to a child possessed of all the senses, in order to render it capable of speaking perfectly? And who would be able to do this in the case of a blind and deaf mute like Laura? Nevertheless, in this little girl the same creative power of the spirit showed itself, which we remark in our own perfectly formed children in the formation of speech, although it does not strike us in them, because we are apt to conclude that the remarkable modes of speaking, with which they so often surprise us, have been caught from others. But this could not possibly be the case with Laura, when she at once put to-

gether words, whose formation and meaning had been taught her by written signs and the movements of the finger, and formed sentences which were perfectly intelligible, although wanting in many necessary words. Thus, when Dr. Howe had gone upon a journey to visit other Institutions of education, Laura asked, "are dumb boys and girls in the schools?" "Will Doctor be very tired?" And when her blind companions were talking with her, in the language of the fingers, of the approaching vacation, and of traveling then, she said to her teacher, "I must go to Hanover to see my mother, but now I shall be very weak to go so far; I will go to Halifax, if I can go with you; when doctor is away, I will go with J——., when doctor is at home, I cannot go, because he must not be alone, and if J——. is away, he cannot mend his clothes and take care of all things."

With the language of words, the peculiar language of the thoughts, man receives at the same time distinct, clear knowledge of himself, self-feeling and self-consciousness. Even this acquisition of the spirit, through the organ of communication which had become adapted to it, becomes apparent to us in the instance of Laura. Thus, one day this remarkable child said to her teacher, "Doctor will come in fourteen days, I think in my head," and to the question whether she did not think in her heart, she answered, "No, I cannot think in the heart, I think in the head." When she was further asked, why she did not think in the heart, she said, "I cannot know there; all little girls cannot know in the heart." On the contrary she said, when she was once melancholy, "my heart is sad. When heart is sad, flows then blood?" Again at another time, when, as it appeared, she was tired with learning, she put the remarkable question, "Why can I not stop thinking? Do you stop thinking? Does Harrison cease to think, as he is dead?" alluding to the President whose death was, at that time, a sub-

when her teacher found herself incapable of making the meaning of a word intelligible, then the ardor of her desire to know assumed the form of impatience. "I will ask the Doctor," said she, "for I must know it."

The natural desire for communication, which belongs to our nature, showed itself in Laura, particularly in the pains she took to assist other children who were deaf and blind like her, and who were brought to the Institution, in understanding and using the language of words. Here she showed herself so ingenious and so active that the teachers found her aid really valuable. The little deaf and blind Oliver Caswell, by no means without talent, and the older but much less gifted Lucy Reed, caught, through a happy device of Laura's, the first light in regard to the relation in which written words stand to the objects which they represent. To assist the former, whose senses of smell and taste were unimpaired, in understanding the word *bread*, she put a piece of bread to his mouth and nose, and she did the same with a fig in the case of Lucy.

In the same measure in which the soul uses its powers to acquire knowledge of external things, it learns to perceive those powers (as already mentioned) in itself, and so arrives at a consciousness of itself. Little children, when they begin to talk, as well as persons of defective intellect, always speak of themselves as of strangers, in the third person. This Laura did when she first began to use words, and when she was hungry or thirsty she said: "Give Laura bread" or "Laura drink water." As soon, however, as she had become more practised in words, and the circle of her knowledge of the outer world extended into the world within, her more perfect self-consciousness showed itself, in that she now said, *I* will or *I* must go here or there, or write this or that letter. When the wisely discerning spirit of man thus takes possession of itself, it immediately attains to a power over the external behavior

and the whole conduct, by which this receives the impress of a moral order. The maidenly grace, the fine sense of the proper or the improper, the right or the wrong, came to Laura not through imitation of other rationally acting human beings, not by instruction from without, but from her own nature, from the innate feeling of the mind, thus perceiving and exercising its will, rationally. How deeply was the lively child grieved, how did her regret speak from every feature of her countenance, when she found that one of her playmates had been hurt by her. The maidenly modesty of the little dumb and blind girl went so far that she would never undress her doll, when she wished to put it to bed, in the presence of Dr. Howe, but always waited until she was alone with her female teacher. While she gratefully reciprocated every token of sympathy shown her by persons of her own sex, she demeaned herself with a careful reserve towards the other sex, declining even to give her hand by way of greeting. As has been observed in other persons afflicted like her, she had a conscientious regard for property. At table she conducted herself with great propriety and moderation. With a perception of the becoming, she had also the sense of the beautiful and pleasing which is characteristic of her sex. Even in the arrangement of her hair and in her dress there was a manifest aim to study ornament, and in new dresses and in every little trifle which belongs to the decoration of the female form, she testified great pleasure, and could not conceal the wish to show herself to others who could see.

From this and similar instances of blind mutes who have shown themselves in their external destitution, as cheerful and happy and intelligent as persons possessed of perfect senses, we learn that the spiritual wealth of human nature cannot be annihilated even though all those noble treasures are lost which are furnished through the bodily senses. Under these infirmities, man may be compared to an opulent individual, whose

wealth is not entrusted to a single ship, far off upon the sea, nor does it consist in splendid edifices which the lightning may strike or a conflagration reduce to ashes, but whose riches are all found in a single costly diamond, which he always carries with him, and who, therefore, always escapes from the wrecked vessel or the burning house, a rich man. Without the senses of sight, of hearing, of smell and of taste, he is destitute of a world of external perceptions and enjoyments, but he keeps the deed of possession, the patent right to the outer world in his interior being, and of course holds possession of the same, for there dwells in him a creative power which builds up within, what he gathers from without. The instinct of the animal turns to something near or distant, something present or future in the visible world, but the indwelling force, which moves man's nature, is directed not to a visible but to an invisible, spiritual world. What the mechanical instinct of the animal weaves or builds, is, however beautiful it may be, nevertheless easily destructible, like the animal which has produced it; but that which the inner force of man builds and creates, is, like the spirit itself, in and out of which it is generated, of an indestructible, eternal nature, and cannot disappear with the senses or the limbs, or waste away in the grave. For as the quail, when it journies over the sea, rests indeed upon many an island, but nowhere tarries long until it has ended its flight toward the goal of its wandering on the other side of the ocean, so the strong desire of knowledge, inborn in the human soul, nowhere finds a resting place and entire content, until it reaches the end of its strivings, the knowledge of a Divine Being, the Creator, in the midst of the beautiful works of his creation. And that, which can exalt itself to the knowledge of a divine being, must itself be of a divine species and nature.

10. VALENTINE JAMERAY DUVAL.

We will consider another instance which may teach us how the force, which urges onward the human mind, as the migratory instinct urges the bird, and leads it from the home of sensible perception into the world of a spiritual knowledge, works its way through all obstacles and outward obstructions, and at last reaches its distant goal, as surely as the stork his nest, when he returns from Africa.

In the before-mentioned case of Laura Bridgman, as well as in other cases of blind mutes, one might suppose that the simple circumstance of their being deprived of all the pleasures of the higher senses, may have kindled the thirst for inward, spiritual activity, and the desire of knowledge. Had Laura, like other sound children, been able to see and hear, then, so it may be thought, her inquisitive spirit would not have shown itself so powerfully as it did; she would have been satisfied with the usual measure of knowledge.

It is indeed to a certain extent true that the spiritual force in men developes itself the more easily and the more powerfully, the less it is dissipated by the enjoyments of the senses, or diverted from its true path. The hovel of poverty has indeed often been the birth-place of great and world-renowned men, but neither the hovels nor the poverty of their parents have made them what they became, but the inward call of the spirit of the Creator in their spirits. Laura, even though she had possessed the usual faculties of the senses, would have been a remarkable child. The celebrated Italian painter, Giotto, who, as a poor herds boy drew figures with charcoal on the rocks, would have been a great artist, even had his master Cimabue found him, not in the field with the cows, but as the son of a nobleman in a rich mansion. For the inward call regards neither rank nor place of birth. It can raise the son of a

peasant slave up to the rank of a distinguished soldier, the son of a poor man to the station of a prime minister. Whosoever is called to a great work in Art or Science, cannot be diverted from his destiny by noble birth, with all its sensual dissipations, nor by the poverty of the paternal abode. The Creator, who feeds the young ravens when they cry, knows also how at the right time to awaken the power which he has placed in human beings, and in the desert, which surrounds them, to furnish it with the necessary nourishment. The great variety in plants, trees and animals, corresponds, in the race of man, intellectually considered, to the great variety of talents and gifts; and as all things are so arranged, that every animal finds its appropriate food and abode, so the tender care of eternal Wisdom is seen still more strikingly when it endows and prepares individual men, each for his future career in life.

With special interest, therefore, will every one who finds pleasure in observing the ways of God among men, contemplate the history of Valentine Jameray Duval, who by the remarkable guidance of his native spiritual force became, from an ignorant, starving beggar boy, the highly respected librarian and keeper of the collection of coins of a great emperor, and through the energy of his own mind, a celebrated scholar.

The time of Jameray Duval's birth, the year 1695, fell in the brilliant days of French conquest under Louis XIV., a period noted also for the great internal distress which France then suffered. Heavy taxes oppressed the land. The flower of its youth were dragged away to battle and there sacrificed; in many places the soil lay untilled for want of laborers, the crops failed, trade and commerce were ruined by war; every where were families mourning for a son or a brother, or father who had fallen in the war which was waged to gratify the ambition of the king. The soil of Champagne is one of the poorest in all France. There lies the little village of Artenay,

in which the house of Duval's parents was one of the meanest. For the father, a poor peasant, died when Valentine was but ten years old, and left to the mother the care of a numerous family, for whose subsistence, the small means remaining to the widow, did not suffice in the then great scarcity. There was daily lamentation in the poor household, the younger children crying for bread, and the elder one's becoming hardened to hunger and toil. Yet in Valentine there was a native power which became only the more indomitable, the sorer the necessity was. What was wanting without was richly supplied from within by a cheerful temper, for he was the liveliest boy in the village, delighting the other children with his fun, and animating their plays with his merry devices. He had barely learned to read in the village school, when in his twelfth year he entered the service of a peasant. The care of young turkeys entrusted to him by his master, during the summer, was rather an irksome business for his lively spirit. It may not therefore be wondered at that the boy fell upon methods of amusing himself, which were not always happily chosen. Among other things he had heard that red colors drove turkies mad. He wished to try the truth of this saying, and accordingly he tied a piece of red cloth round the neck of one of his flock. The animal fell into violent rage, struggled in vain to free himself from the cloth, and then, not allowing himself to be caught or held, fluttered about until he fell dead. His master immediately drove the boy from his service, and as no other employment was to be found in the village, and his mother was too poor to support him, he set off to find subsistence abroad.

It was in the winter of 1708–9, unquestionably the severest know for a century, when the boy Duval commenced his first wandering in the broad world. The cold, which reached its greatest intensity after Epiphany, January 5th, 1709, was so frightful that no one ventured to leave his house or his fireside

without the most urgent necessity, for accounts were daily heard of persons found frozen to death on the highways and in houses. All places of public assemblies, the courts of justice, and even churches were deserted. Wine and water could not be kept in a fluid state for the service of the altar. Wine in cellars hardened into ice. The cattle in their stalls perished, the animals in the forests, quadrupeds and birds approached the dwellings and hearths of men to seek protection there against the terrible cold, and food, which was elsewhere buried deep under the snow. Birds fell powerless from the air, the fish died in the ponds, which were frozen to their lowest depths. The seed in the fields and the vines were ruined, trees in gardens and even the trunks of forest trees snapt with the cold, rocks were split and thrown down. It was several years before the traces of the desolation which that winter had caused were in any degree obliterated. Vineyards and olive plantations had to be laid out anew. For more than a generation maimed people were to be met with on crutches, who had lost their limbs not in war, but in consequence of freezing, under the knives and saws of the surgeons.

Even in those days when the winter began to be the hardest, young Duval wandered, from place to place, along the deserted roads, to seek service and a refuge from frost and hunger. To both these perils, there came a third, the hardest of all, which threatened to put a sudden end to his life, and which was nevertheless sent to his rescue from the otherwise inevitable death by freezing and starvation. On the way between Provence and Brie, near a farmer's house, he was seized with so terrible a pain in his head that it seemed to him as if the bones of his scull would break apart, and his eyes start out of their sockets. With difficulty could he drag himself to the door of the neighboring house, and implore the person who opened it to him, to show him a corner where he might warm himself and

recover from the distressing pain. He was shown the barn among the sheep, and the gentle warmth which was diffused there by the breath and perspiration of the numerous animals, was more beneficial to him than a heated room in the best dwelling house could have been. His limbs soon lost their stiffness, but the pain in his head became so violent that it robbed him of his senses. When, the next morning the farmer entered the barn and saw the boy's eyes sparkling and inflamed with fever, his swollen countenance covered with red pustules, he was not a little startled. He instantly told the poor sick child that he had the small-pox and must certainly die, because he was too weak and wretched to go or to be carried to a place where he would be better taken care of, for there in that poor house there was no means of affording him the scantiest subsistence during so long a sickness. The sick boy was unable to speak a word. His condition touched the farmer; he went into his house and brought thence a bundle of old linen rags, in which, after he had with difficulty undressed Duval, he wrapt him as a mummy. There in the barn lay the dung of the sheep heaped up in rows; between these the farmer made a couch of the chaff which had fallen from the winnowed oats, laid the boy upon it, covered him to his neck with chaff, and then with layers of the manure. As when a dead body is deposited in the grave, the compassionate farmer, when he had finished the work of covering the boy up, placed a cross over him, commended him to God and his saints, and as he departed repeated several times the assurance that only a miracle could save him from the death, to all appearances, so nigh at hand.

It needed not this assurance to fill the mind of the sick boy with thoughts of his end; he felt himself at the point of death, and the benumbing of his senses, which, from time to time, crept over him, appeared to him already the beginning of the

death-slumber, which, in his half dreams, he saw approaching without dismay or fear. But the miracle of divine Providence, which alone, as the farmer had said, could save him, had already begun. He had found just at the right moment this healing covering, and a sort of instinct had suggested to the farmer this mode of taking from the disease its fatal power, a mode, singular indeed and most offensive to the senses, but at the same time most serviceable in the present instance. The warm breathing of the sheep that lay around his grave, the warmth which his grave itself diffused all over him, excited a salutary perspiration and mitigated the virulence of the disease. The violent headache and the stupor were removed; to the eye of another, his situation was loathsome to look at, but to the boy himself, it was quite tolerable.

While Duval thus lay buried in the sheep-stall, and had nothing to complain of but extreme weakness and a gradually returning appetite, the winter raged without with ever increasing violence. Several times, at night, he was awakened by a noise like thunder or a discharge of artillery, and when he inquired of the farmer, in the morning, the cause of this nightly alarm, he told him that the frost had split one or more of the walnut or oak trees that stood near, from the root up, or that by the freezing of the moisture in the crevices of the rocks, the rocks had exploded as if by gunpowder. Without, on the roads as in the hovels, men daily froze to death. The farmer himself in his poor dwelling could scarcely, by the flaming hearth, keep himself from freezing; while Duval was as comfortable in his strange situation, and among his brutish attendants, as the king or a prince of France, in his well guarded room.

Nevertheless, this good fortune was not wholly uninterrupted, for in the midst of his comfortable feeling of repose and the moderate warming of his feeble limbs, as the disease abated,

the plague of hunger set in. The shepherd who had taken on himself according to his ability the charge of the boy, was a very poor man. The exorbitant taxes which the rich King of France had imposed on his poor subjects, had taken from the farmer almost all his household utensils, his cattle, and the things indispensable to the culture of his fields. The sheep alone remained, because they were not his, but belonged to the proprietor of the estate. The good man did, however, what he could. He gave his poor patient twice every day a thin water broth, which had no condiment but salt, and even this so sparingly that it was scarcely to be tasted, for even salt was taxed so heavily, that poor people could hardly supply this want. A corked bottle was the vessel in which the oat-broth was brought—the only way in which it could be kept from freezing —the boy keeping the bottle close to him in his warm bed, and taking a draught from time to time. The water which was brought to him was frequently half frozen.

For some weeks this food sufficed to allay hunger, but soon the increasing strength of the boy demanded more nutritious diet. But the poor farmer could afford nothing but a watery soup and some pieces of black-bread, which were frozen so hard that they had to be cut with an axe, and only the warmth of the mouth or of the bed made them eatable. As trifling as these gifts of a love, which received not its reward on earth, may have been in the eyes of men, they soon exceeded nevertheless the ability of the poor farmer, who saw himself compelled to apply to the clergyman of the village for help for his patient. His application found a hearing. The abode of the pastor was almost a league distant from the sheep-fold. Thither Duval was carried after being taken from his grave, wrapt in rags and hay, and seated upon an ass. The cold was still so severe, and the change so great, that he arrived at his

new shelter half dead and with every limb stiff. To prevent the injurious effects of the frost, his body was rubbed with snow, and he was placed in a situation which, in its character and fitness to create a moderate warmth, was as well adapted to him as that from which he had been taken in the sheep-fold. Only after a week, when the cold had considerably decreased, was the patient, again becoming strong, carried to a chamber and laid in an ordinary bed. The care and food which he received in the parsonage, were indeed much better than the poor shepherd had been able to afford him. Duval soon felt himself as well and as strong as he had been before his sickness. With the return of health came also the inclination to wander. The good pastor could employ no additional servant in his little household. He intimated to the now vigorous lad that he should look about him for employment, gave him a little traveling money, and dismissed him from his kindly care with his affectionate blessing.

Just at that period there was the greatest difficulty in finding employment in Champagne. There would indeed have been a demand every where for laborers, for the reckless, violent levying of recruits for the army among the youth and men had taken from the herds their keepers and from the land its tillers, but, as useful as the labor of a robust young man would have been, it could not be taken advantage of: every master of a family, where any such were, had trouble not only in securing bread for himself and his dependants,—he could share the little yet to be obtained, with no new comer. As we have already said, the extraordinarily severe winter had annihilated almost all hopes of a harvest for this year either for the farmer or the vine-dresser. The collectors of the taxes, the forestallers of grain, who refused to sell in hopes of yet higher prices, asked not about the distress of the poor people, they were almost as hardhearted as their king, Louis XIV. Like him, they thought

only of satisfying their greed, even though thousands perished, and the suckling died at the breast of its starving mother.

Jameray Duval, as he thus, without finding employment, went from village to village and from farmyard to farmyard, and every where saw nothing but bitter want, and heard of nothing but scarcity, dearness and starvation, asked at last, whether there were not any other country, where the grain was not frozen. He was told that, perhaps, towards the East and the South, there might be regions which the warmer influence of the sun had protected against the devastations of the winter. This intimation filled the heart of the young wanderer with joy and hope. In his apprehension the world appeared, as it seems on a serene day to the inhabitants of a plain, to be a dish-shaped expanded surface, upon whose rim the crystal concave of the sky rests, over which the sun passes by day, while the stars are lighted like lamps at night, to be extinguished in the morning. The sun, itself, as it is represented in the almanac like a human head, the boy held to be a living being of fire, of which it seemed to him altogether probable that it must give the most warmth where it was nearest to the earth, and that was in the eastern horizon, at its rising. Resting in this belief, our Valentine now directed his course to the quarter where the sun rose. The commencement of his journey did not appear fitted to animate him to its continuance; it led him through the poorest parts of Champagne. The low, clay-built huts, covered with reeds or straw, with their inmates clad in rags, whose withered countenances, pallid with want and trouble, seemed, like the wasted features of their half naked children, capable of no glad smiles, but only of weeping, were well adapted to appal his love of wandering. In addition to these things there was the want of the most ordinary means of subsistence, a want shared alike by the vagrant and the inhabitant of the land. Instead of what might properly be called bread,

a baked composition of crushed hemp-seed appeased the hunger of the people. Duval had need to be thankful, if he could only procure enough of this unwholesome food to allay his appetite. But the benefit was only apparent; he acquired no strength, but a disagreeable sensation in the head was produced by this diet, of which he was not free for years afterwards. All this, however, could not obstruct the career upon which he had entered, impelled by a mighty inward impulse; he pursued his way, with all possible speed towards the East. Traveling in this direction, he came one day to the top of a hill, at whose foot lay a not very attractive looking district (Bourbonne les Bains). A thick vapor, which rose from its midst, appeared to the young wanderer to be the smoke of a conflagration just being extinguished. He was not a little astonished when he was told that it came from the hot springs, which there rise out of the earth. Such an unexpected piece of information excited his curiosity in a high degree. He ran to the springs, laid himself down on the ground, put his hand several times into the bubbling water, but had to withdraw it quickly, as the heat was too great to be borne. Thereupon, in childish ignorance, he pursued his further inquiries. Nowhere was a stove or fireplace to be seen, which might make the water boil so. "What," he thought, "could any one suppose but that this was the neighborhood of hell, and only great levity could have thought of building and dwelling on such a spot."

From this supposed vicinity of hell, our young wanderer came the next morning upon a landscape which, by its blooming appearance reminded him of the neighborhood of Heaven. The annoyances and troublesome inquiries, which now obstruct the traveler as he passes from one little country to another, were then unknown. Duval had, without knowing it, passed the boundaries of oppressed, exhausted, France, and had come into Lorraine, which at that time was still under the mild

government of its German princes. What a difference was there already between the first village of Lorraine, Senaide, and those parts of Champagne through which his direct route from west to east, had led him! Here were no longer to be seen those poor, low, rush-covered clay huts, with their pale, wasted inmates, but high and well walled houses, roofed with tiles, and occupied by beings, whose well fed persons and fresh complexions spoke of ease and comfort. How merry, round-cheeked and beautiful were the well clothed children, in comparison with the children of the French borders, half naked, and pining away in dirt and misery.

It was Sunday; the sound of bells called the people to public worship in the well built spacious church; even Duval, thankfully glad as he had hardly ever before been, hastened thither. Here every thing that he saw seemed new and beautiful, the armorial double eagle over the door of the vestibule, the dress of the people, so grand in his eyes, the multitude of young men, whom no tyrannical force tore from their homes and families, to be sacrificed to the insatiable ambition of an oppressive king. Instead of the poor frocks of coarse ticking and sack-cloth, which his countrymen wore, our young wanderer saw the men of Senaide clad in becoming clothes with silver buttons, and the women with short sleeves and ruffles, as richly dressed as the best ladies of the cities of Champagne. Here the clatter of the heavy wooden shoes was unheard, in which the country people of Champagne put their bare feet, for even the poorest were provided with shoes and stockings. And not only the eager eyes but the famished stomach of the stranger found food here. Instead of the nauseous hempseed bread, there was sweet wheaten bread, with meat and other articles of food, all which the liberality of the villagers offered for almost nothing. It was good to be here, so Duval thought, here was the land to which the warming sun was nearer at its rising

than to the rest of the earth, here he wished to remain. And the wish was gratified. The people were able to employ and support laborers. The shepherd of the near village of Clezantaine took the robust, active boy into his service.

Two years long Duval tended the sheep on the hills of Clezantaine, and was comfortably supported. He was now sixteen years old, and tall and strong for his age. That inward force which had led him hither, as the bird is led by instinct, began to stir anew; but not in a mere animal way, impelling him to seek the stilling of his hunger and a place of bodily well-being, but in a human, spiritual way, and on this account he was moved all the more powerfully. This impulse, which left the youth no rest, aimed at other satisfactions, was directed to a higher repose, than the physical world could furnish. It was directed to the unfolding, not of the outward but of the inward, spiritual man. Our herds-boy felt that something was wanting, but what, he knew not. When alone in the fields, he saw the trees and flowers, the beasts and stones; when the moon stood, now in the evening sky, as a sickle or growing disk, and showed him his way home, and now again, in its waning, when it brightened the morning hours, then he fell into deep thought about all these things, and the changes they underwent, till he could find no beginning and no end. Where the little brook, which flowed by the village, had its beginning, he knew, for in summer he visited its fountain almost daily, but whence the water came, that always rose out of the earth, he could not ascertain; and that the brooks united in rivers, then into bays, and then ran into the sea,—this he knew from hear-say, but he would gladly see and know it with his own eyes. When the neighbors sometimes came together at the herdsman's, or when, on Sundays and holidays, the villagers, and perhaps a stranger among them, fell into talk before the church, he listened with the utmost atten-

tion to all they said about war and peace, of events taking place here and there, of other lands and places. He had ever to ask, wished always to learn more; but what these good people told him only stimulated instead of appeasing his curiosity. From the height, on which Duval often tended his sheep, a landscape was to be seen, among the most fruitful that comprehended Lorraine, green meadows and fields, amidst which lay a multitude of little farms, extended as far as the eye reached, from the north toward the south, to the foot of the blue mountains of the Vosges, which bounded the prospect to the east. There, on those blue mountains, Duval longed to stand and see what lay beyond, for this much he had learned, that the world was much greater and more extensive than the circle of his vision.

That, which had been sometime before only a pleasure to his eyes, now became the joy and desire of his heart. Duval could no longer resist the impulse which urged him to quit his present place. He parted from his employer, and once more resumed his wandering towards the east. There, at the foot of the Vosges, not far from Deneuvre, a pious hermit, brother Palemon, had, about that time, his hermitage, called by the country people by the name of La Rochette. A more delightful abode for a solitary, who wished to live with his thoughts on God, far from the noise and disquiet of the world, could hardly be found. From the top of the rock, on which the hermitage stood, one could see the sun descend behind a green undulating plain, through which wound a river, which floated the ship timber, bound in long rafts, down to the sea-coast. On the opposite (the eastern) side, the beams of the setting luminary fell upon the slope of mountains divided by beautiful vallies and ravines, and adorned up to their tops with fine villages and country-seats. With the fragrance of blossoming trees and shrubs, the tones of the nightingale rose to the wanderer seated on the rock. Duval cou'd not quit the

spot; at least one night and the next morning he resolved to spend in this place, he begged the hermit to give him a resting place in his hut, and his request was granted.

It was that all-considering Providence, which brings together what belongs together at the right time and place, that had directed Duval's steps to the hermitage of La Rochette. Brother Palemon had need of just such a young useful assistant, who could help him in his garden, and in various other things. The true-hearted lad, whom God himself had led to him, pleased him well, and nothing could please Duval more than to enter into the service of brother Palemon.

We have said already that Jameray, when the great poverty of his mother compelled him to quit the village school and go into service as a keeper of poultry, had barely learned to read. This art, obviously one of the most important among all the arts which man can make his own, was, and always continued to be, highly valued by him. He had impatiently waited for an opportunity to practise it. But such opportunities had hitherto been very few. What of readable matter was to be found in the house of his former master, the shepherd, consisted only of an almanac and a mass-book. The lively curiosity of the boy found therein little nourishment. But here, in brother Palemon's dwelling, there was a whole library, of books never before seen, which numbered more than twelve volumes. Besides one or two parts of a then popular work, which bore the name of the "Blue Library," the literary food of the pious hermit consisted only of such works as contained directions to a contemplative life, prayers and meditations, lives of saints, and accounts of monks and hermits.

With a burning desire Duval seized this spiritual nourishment. He applied himself earnestly to become the companion of the good Palemon, not only in the labor of the hands, but also in prayer and a devout life. Upon a spring morn-

ing, when the dew rested in pearls on the flowers, and the song of the nightingale was heard, as he sate upon a point of the rock above the hermitage, and the sun rose above the heights of the Vosges, his mind rose to an unwonted elevation. But he had now to learn what many before and since have experienced, when in this exaltation of mind, they have forgotten the wisdom of the lark and the eagle, who, in their ascending flight direct their eyes upwards and not below. Whoever rises on the wings of devotion like the lark, sees clearly, that, although he hovers above the roofs of human dwellings, and even the pinnacles of towers, he is still far below the mountain tops, still farther beneath the clouds, and much farther again from the starry heavens. But whosoever, as he rises, looks only below and not above, and perceives below him the oaks of the forests, which are still high, as low shrubs—to such an one it may easily happen, that, seized by the dizziness of pride, he is in danger of tumbling to the earth. Our young novice in the hermit's life had this experience. Because his youthful ardor was more lively than the feelings of his older companion, because the outward expressions of his devotion were more imposing than those of the quiet, gentle brother Palemon, Duval fanced himself exalted above his friend. When Palemon gave him something to do in the garden, or sent him on an errand to Deneuvre, the lad, instead of complying, gave himself up to his devout meditations in the shade of the rock or under a tree, and to the well-merited reproof of his neglect, he replied only by bitter remarks on the lukewarmness and worldliness of his elder brother. The giddiness of pride was certainly not to be mistaken here. Experiences, fitted to set him right, our young hermit would not indeed have wanted, had he only been always open to such instruction. Thus, on a certain evening, when four canons from Deneuvre

stopped at the hermitage, and partook of refreshments which they had brought with them, and the remains of which were given to Duval, for the first time in his life he learned the power of wine, the effect of which he considered as the influence of the highest devotion, until the feeling of exhaustion the next day taught him otherwise.

His residence with brother Palemon continued only a short time. The superiors of the Eremite-association sent one of their members to La Rochette, to whom Duval had to submit. His kind master gave him a letter commending him to the hermits of St. Anna, at Luneville. Our young eremite had not proposed to go thither, of his own mind and inclination, but as he was now diverted from the direction in which he himself first chose to travel, towards the east, so it was a higher hand that, at this stage of his career, led him against his own wish and will to the right goal. The sorrow which he felt in parting from the quiet shelter of La Rochette and from brother Palemon was as transient as that which he felt when he was taken from his strange bed in the sheep-fold, and carried, wrapt in hay and rags, to the house of the good pastor where he was restored to health. Those ways of Providence, which best serve our welfare, are generally opposite to our wishes; they cross our own ways, and yet lead to peace, while the ways we would have chosen lose themselves in pathless wastes.

With anxious heart Duval wandered through the forest of Modon into the open country, where lay before him the flourishing city of Luneville, with its beautiful castle, the residence of the Duke of Lorraine. Uneasy as a wild bird, brought for the first time in the new prison of his cage into the crowd of a market-place, our young hermit mingled shyly with the well-dressed throng of this metropolis, and hardly dared to turn his eyes to the grand castle of the prince, which seemed to inti-

mate the neighborhood of beings of a higher kind. He breathed freely again, only when he found himself again clear of the city on the road to the west, which had been shown him as the way to St. Anna.

The hermitage of this name lies a half league on the other side of Luneville, on the southern side of a hill, near the spot where the Meurtre and Vesouze unite their waters. The forest of Vitrimont, which borders them to the north, much thicker then than now, increased the beauty of the country, while in winter it kept off the cold wind from the north, and in summer afforded shade and coolness. But a few years before, the spot now highly cultivated had been a waste of thistles and thorns, which still showed traces of the desolating times of the thirty years' war. A former lieutenant of cavalry, who, severely wounded in battle, had been left for dead under the hoofs of the horses, and had been restored to life, without any desire, however, to return to its active pursuits, was the founder of the hermitage of St. Anna; and only a few years before had died nearly a hundred years old. Brother Michael, so the founder was called, had purchased an old mansion named Alba, near the forest of Vitrimont, had associated with himself some other individuals, and with their assistance had transformed the barren spot, which comprised twelve acres of land, into an estate, the produce of which supported six cows, and four or five men, who, without needing assistance, were able to give charity to others. In several other quarters, also, the good brother Michael had made himself useful by similar establishments, in promoting the culture of the land and the improvement of individuals; for several of the companions of his lonely life had previously been vagrants, who, first led by necessity, became bound to him by love; and the influence of his example, the force of his sincere piety, transformed them into better men.

Duval, in anxious expectation of his fate, presented himself at the door of the Hermitage. Brother Martinian, one of the four inmates received him, and returning his greeting, took from his hand his letter of recommendation, introduced him to his brothers as a future servant of the house, bade him be seated and partake of the rustic fare which he placed before him. The new-comer soon felt himself at home among these good people. They were men of peasant-like appearance, but of true hearts. They had indeed, not that finely cultivated sense which teaches politeness and grace, but the yet more tender feeling of hearts under divine discipline, which tells us what is right and guides our steps in a straight path. Duval bears witness particularly in regard to three of these individuals; that they never indeed talked about virtue, but practised it unseen by the world. His five years residence among them showed him in these simple souls no trace of impurity or hypocrisy, but only the ordinary foibles of our nature. The heart of old brother Paul, who had then dwelt two and thirty years in the hermitage, had become a temple of humility and love; and the inward peace which such a temper gives, showed itself in his whole deportment. He spake less, but did more than the others, for, as he said, it happens with us, with the best will that we more easily and oftener sin in words than in deeds. He was gentle, patient, tender-hearted, and so invariably cheerful that it seemed as if no emotion of human passion could disturb his spirit. Nothing took him by surprise; in thunder and lightning as in the stillness of a spring morning, in cold as in the heat of summer, he remained in the same even state. He did not seem able to comprehend how one could hate, and when Duval once asked him in jest, whether one might not at least hate the devil, the good man replied with grave simplicity. "We must hate no one."

The first business which the old hermits intrusted to their robust young mate was the care of the cows, which he had to drive to pasture in the forest. This employment was not entirely to his taste. From all such mean occupations he had believed himself free from the time he had quitted Clezantaine. His residence with brother Palemon had produced and nurtured in him the notion that he was destined for something better than tending cattle. Yet a glance at the kind brother Paul and the grave face of brother Martinian taught him silence and obedience. With whip in hand, he drove his cows to the forest. Self-conquest, the victory gained over a proud self-will is always a rich source of peace. Our young herdsman soon performed with pleasure the service, which at first he had undertaken with no good will.

The honest fathers wished, not only to train their pupil to rustic employments, but also to educate him for their society and make a scholar of him also. One of them, who, in comparison with the others, represented the learned man, and valued himself somewhat on the score of this privilege, had learned the art of writing, and when he remarked the extraordinary curiosity with which Duval's eye followed his pen, he resolved to make the lad a sharer of his art. With a hand trembling with age and daily toil, he wrote for the youth the letters which the latter faithfully copied, forming them as rudely as they were represented. But the zeal of the pupil exceeded the ability of his old teacher. The one rarely had time to teach, the other thirsted continually to learn. Duval invented, therefore, a method by which he might practise himself in writing without assistance. He took a pane of glass from the window of his cell, laid it over a written paper, and with the ink, which was easily washed away, traced the letters on the glass, until at last he was able to write a stiff, old fashioned hand like his teacher. In the religious exercises of the place, which

consisted of six offices of devotion, observed in common every day, the future eremite was also regular, except when the care of the cows kept him away.

But Duval's education in the hermitage of St. Anna was not confined to the art of writing. He found other means of feeding his daily increasing appetite for knowledge. The good fathers possessed several books. The cover of one of these was a rich prize to our young inquirer. It contained the first four rules of Arithmetic. The delight which a poor man feels, when he unexpectedly digs up in his little garden what seems to him an immense treasure, could not be greater than Duval's, when he found the key to an art, which justly appeared to him as one of the gates which open into an immeasurable realm of knowledge. Sums appeared and vanished before his eyes, as they were united by addition, or yet more increased by multiplication, and again diminished by subtraction, or still farther lessened by division—what enjoyment was thus afforded to a mind which in the signification of numbers discerned the means of comprehending in material phenomena, the powers or properties with which the all-creating spirit has endowed the same. The young hermit had always during his herdsman's life found a special pleasure in the stillness of the woods and quiet pastures. Here at St. Anna he could enjoy this pleasure in a high degree; for scarcely any other forest resembled in loneliness and quiet this of Vitrimont, with its little vallies and ravines. At his favorite spot, a sort of grotto, the remains of an old quarry, the diligent arithmetician was often found, even in the hours of the summer night, busy with the solution of self-imposed tasks, or with weaving those thoughts which germinated in the narrow, but so much the more fruitful, east of his daily experiences.

We m powerfully than by all that he saw around him, was he cted by the spectacle of the starry heavens. The frequent

eading in the Almanac had already at Clezantaine afforded im an indescribable pleasure, because the course of the moon or a whole year was therein foretold in a way to him incon-eivable and prophetic. Then too, he learned something of hose heavenly signs of a ram, a bull, a lion and a crab, into which at certain seasons the sun and moon entered. Brother 'alemon had told him, that those signs of which the Almanac peaks, were to be found among the stars of heaven, but how, r where he knew not. Even the hermits of St. Anna could ive him no information. But our Duval had no rest, he must nquire and know where the goat or the bull kept themselves idden among the stars of heaven. On one of the highest oaks n the edge of the wood he built for himself out of willow-twigs nd ivy, a sort of throne like a stork's nest; the throne itself pon which he there sat, was the remains of an old bee-hive. Here in clear nights he spent many an hour, during which he xamined with the closest attention every quarter of the Heaven, n order perhaps to discover among the stars the form of one f those celestial animals. It happened with him, however, as vith the deaf and dumb child, for whom the word '*tree*' has een written down, while the meaning of the word is defined in picture or by the language of signs, and who in vain endea-ors to discover a resemblance between the written sign and he form of a tree.

As in the material world, at the right time hunger finds its ood, and every awakened want its supply, so is it in the spi-itual world. The sound and honest impulse towards know-edge is under the care of the same Providence that directs the orce of animal instinct to its goal. Whatever helps to invigor-te and unfold, is furnished at the right time. It was just at he time of the great annual fair of St. George, at Luneville, hat the hermits sent their young servant into the city, to exe-ute certain commissions. While curiously gazing at the beau-

tiful things exposed for sale, he discovered, to his inexpressible joy, a celestial chart, a representation of the earth and four maps representing the four quarters of the globe. The wages he had earned at Clezantaine, remained almost entire in his possession, and this treasure, amounting to five or six francs, he had with him always in his pocket. The moment had now come to make a right investment of this hitherto dead and useless capital. With joy he gave it all to secure possession of the precious charts.

In a few days the happy Duval had got so far in the celestial chart that the relative situation of most of the constellations was known to him; it became plain to him, also, that the pictures on the charts were not drawn on the heavens, but that to every picture a group of stars belonged, which had little to do with the form of a bull or a ram. Had there only been some one to describe and name to him one of these groups, it would have been easy for him, according to their relative places on the chart, to find out the other pictures also, but he had himself to devise a means of escape from this embarrassment, and his reflections soon led him the right way.

He had learnt that the pole-star, which designates the north pole of the heavens as well as the earth, always occupies the same place. Could he only find this, so he inferred, then he would have at all hours of the night, in summer and in winter, a fixed point from which the relative places of the constellations would be ascertained. But who was to tell him where to find in the heavens the north pole? In this uncertainty, a piece of information he had got by hearsay became of service. He had heard that there is a steel needle which always turns one end toward the north, and might therefore serve to ascertain the different quarters of the world. His earnest desire to see such a wonderful needle and make use of it, was gratified by one of the old hermits who had in his possession a

pocket compass, and willingly lent it to the eager Duval. The direction in which the pole-star is to be seen, now became known to him, but how high or low the north star stands, he knew not. This important discovery, however, was made after several vain inquiries and failures. He first tried to find the pole-star by means of a straight branch directed towards a star of the third magnitude, standing in the north. By boring this branch, he made it a tolerably large tube; if the star to which this instrument was directed was the true one, then it must always be seen through the tube. But alas! the tube was scarcely bored when the star, to which it was directed, passed from the field of vision; and not more fortunate were other experiments until at last the tube broke. Yet the curiosity of our young inquirer was not diverted from its path by such disappointments. A reed of elder, from which the pith was removed, was next fastened to the top of the large oak, that served for an observatory, in such a way that it could be turned at pleasure, up and down, to the right or to the left. This contrivance led at last to success; the pole-star was found, and therewith the key to the gradual explanation of the starry groups, and to a knowledge of the constellations.

When the living thirst for knowledge is awakened in man, it never rests satisfied with inquiring into what lies before the eyes. Even the salmon, when the migratory impulse begins to urge it, is not diverted from its course, when at one time it ascends to the source and at another descends to the mouth of the stream. So the mind of mind of man, in the midst of the visible world, is bent upon knowing the beginning and end of all phenomena. What are these stars, Duval asked himself, and how far is it to them from my oak? More fruitlessly now, than when before he possessed the charts he tried to find the signs of animals in the heavens, did his eye exert itself to find a measure below for the things above; on all sides the desired

end retreated before him; the nearer he appeared to come to it, the farther did it retire into the depths of infinity, which no inquiries of the senses, but only the inward eye of the spirit can penetrate.

Whatever may be the size of the earth, that would be more easily ascertained, so thought our advancing scholar, if the representation of the earth, which he had lying before him, could only be understood. His charts were his constant companions. In the lonely woods he spread them on the ground before him, while the cows grazed around him. What the many lines, some straight and some curved, which were drawn upon the representation of the globe—what they meant, he thought deeply for days. At last the broad girdle drawn around the middle of the earth, and divided into three hundred and sixty little black and white spaces, led him to think that they were intended to represent distances. A light rose upon him, which at once made all clear; the riddle was solved; the little spaces signified miles (he knew as yet no other measure for earthly distances,) and consequently he considered that the circumference of the earth consisted of no more nor less than three hundred and sixty French miles or leagues.

He could scarcely wait for dinner time to communicate his grand discovery to the hermits. The learned brother shook his head, but had nothing to say. One of the others had been, in his youth, at St. Nicholas de Barry, in Calabria. He stated that on that journey he had traveled more than three hundred and sixty leagues, but that land and water extended farther; a distance of three hundred and sixty miles could not reach round the earth.

The poor Duval stood there now with his discovery, ashamed and at a loss; either the charts, for which he had sacrificed his whole property, were good for nothing, or the key to them lay so entirely hidden from him, that he must give up the hope of

finding it. But even on this occasion, as it always opportunely happens in the animal and in the spiritual world, his awakened desire found its gratification. Our young hermit was accustomed to attend mass at Luneville every Sunday, and on these occasions to execute various commissions for the brethren. On the next day after the disheartening event, which had befallen him in the career of his investigations, he made his Sunday visit to the city, and at the close of the mass, walked a while in the garden of the monastery. There he saw Mr. Remy, the gardener, seated at the end of a walk, reading. His curiosity, always awake, prompted him to ask what the gentleman was reading, and to his joyful surprise, he learned that the book was an Introduction to the learning of Geography. It was De Launai's little geography, very popular at the time. Poor Duval burned with desire to read the book; he ventured the entreaty, that Mr. Remy would lend it to him, and his request was complied with. With the intention of transcribing it, he took the book with many thanks, but could not resist the desire immediately to know its contents. Already on his way home, he learned that the little black and white spaces on the central line of his representation of the globe, denoted *degrees*, every one of which was twenty-five French miles, fifteen German geographical miles, and in every country, according to the difference in the length of its miles, a certain number of that common measure of distance. He immediately learned also, what the other lines meant, which cut the central line or the equator, from the north to the south. He thought now of nothing but making himself a globe, in order to the better understanding of what he had learned. Hazel-sticks bent to represent one way the length, and the other the breadth of the earth, were fastened together horizontally and perpendicularly, and then notched with a knife to represent three hundred and sixty degrees in one direction, and

ninety in the other. Now first was the distinct understanding of his charts laid open to our inquiring young hermit, when he spread them out upon the ground under the shelter of the wood, and by aid of the compass which he had borrowed, arranged them in the due directions. Then his inquiring spirit could wander forth from the point where Luneville lay now to this country, now to that, in this, or the other quarter of the globe, and shortly he could answer promptly and with certainty any question about the situation of this or that place. Not content with this, he sought out in De Launai's Geography, the coarse of the rivers and the outlines of the sea coast, noted on both, the situations of remarkable cities, especially of the capitals. His success was such that, after a while, he was as familiar with the several cities on his charts, as their own citizens, and as he was with the different parts and trees of the woods near St. Anna. Other thoughts also came into his mind, which attracted him on to still further investigations. The broad expanse of water on the globe, in comparison with the much smaller portion of inhabited land, filled him with astonishment. What kinds of living creatures, so he asked himself, are moving in the depths of the sea, and for what are they created, since man, the lord of the earth, cannot see nor know, much less make use of them.

The longing for knowledge in Duval had risen to a passionate heighth.* It was now directed especially towards other countries, of which he thought all day and dreamed by night; the circle of his knowledge had extended in other directions. In every house, whither the errands of his old masters led him, he inquired for books; and where books were to be got, if he could not find one, he took another. In this way a translation of Plutarch's Lives and the history of Quintus Curtius had come into his hands, and became his amusement in the retired grotto of the old quarry. But all these new elements of know-

ledge were the sparks which kindled the desire to know more. The whole earth with its countries, not only as they are now, but as they formerly were, when other races inhabited them, he longed to know. Before every old wall, before every monument of past times, he paused with reverential thoughts; he contemplated every stone, every inscription, and would gladly have understood their language, to learn who had dwelt there, and what were their fortunes.

Books, in his innocent over-estimate of human wisdom, seemed to teach and tell all things. But how was he to procure books, after he had spent all his wealth in the purchase of his charts? The booksellers, old and new, whose shops he often visited, devouring with greedy eyes, the titles of the books, when nothing more was permitted, would not so much as lend their treasures. What one wished to obtain from them, could be had only for money, but money,—where was this to be gotten?

A spiritual force, like that which stirred in Duval, breaks for itself a path through all external obstructions, and powers are developed unknown to one who has grown up surrounded by abundance. Duval had learned that the skins of certain wild animals, as well as the flesh of others, were sold in the city, at greater or less prices. In that portion of the forest belonging to them, the proprietors of St. Anna had the right, not only to pasture their cows, but also to hunt and catch the game, birds and quadrupeds. The former owners of the place had exercised the latter right to its full extent; but since that resort of the huntsman had become, by brother Michael's purchase, occupied by quite other inmates, and the forest, with its wild animals, was the property of pious, peace loving hermits, it had fallen under the power of those four-footed tyrants of the wood, which the huntsman justly pursued as hurtful. Martens and pole-cats, foxes and wild cats, here perpetrated their mur-

derous deeds undisturbed, for the good old brothers had neither guns nor other fire-arms, they made use of neither snares nor poison, in order to execute justice, as would have been their duty, upon the robbers and murderers in their domain. When Duval saw the nightingale, whose song delighted him, bleeding in the talons of the wild cat, or the young of the thrush or the robbin carried off and destroyed by a nightly attack of the blood-thirsty marten, he was not disposed to allow such things to be. The lament, which the parent birds raised the next morning over their empty nest, touched him deeply. The birds uttering their melancholy longing for that which they had loved and possessed, stirred in him a melancholy longing for that which he too loved but did not possess. Both might be assisted. The cries of the innocent sufferers called for retribution, and the murderers must atone for their guilt with life and wealth, and upon whom could the office of avenging the birds better devolve than on him who exercised the authority of judge and avenger with a powerful hand. No other transferable property was found on the guilty than their fur, and this Duval appropriated to himself.

The old fathers of St. Anna, although they lived on terms of neutrality and peace with the wild inhabitants of the neighboring wood, sometimes experienced an emotion of irritation against their bold, four-footed neighbors, when they discovered sometimes of a morning that their geese had been robbed by the fox, and the poultry murdered by the marten and the polecat. They made no objection then, when their young attendant joined to his office of herdsman, the business of a hunter and came home, now with the trophy of a fox-skin, and now with the felt of a marten. How the strange lad, without gun, lead or powder, armed only with bow and arrows, succeeded with various ingenious traps in catching the cunning fox and the shy marten, the brethren heard often with admiration. But his

hunting was not always without its dangers. One day he entered the common room, bleeding with many wounds and covered with blood, with a dead wild cat borne on a stick as a trophy. He had boldly chased this murderous animal until, wounded on the head by his club, it took refuge in a hollow tree. There, in its hiding hole, he worried it so with his stick, that the animal at last rushed fearlessly out and sprang upon his head, which it tore with its talons and its teeth, until the stout youth tore it off and dashed its head against the trunk of the tree. He called quietly to the terrified fathers: "Don't be frightened, reverend fathers, no harm has happened to me. You see here the murderer of our singing birds. I have conquered him, and washing with a little water and wine will soon heal my wounds."

To the officer of justice, who inflicts the punishment of death on criminals, rightfully belongs, not only their moveable possessions, but also all their remaining property and income, as their natural heirs are like them outlawed, and have fled the country. The revenues of the foxes and martens consisted particularly in the flesh of hares and woodcocks, and in the autumn, now and then, of snipes. Of these Duval appropriated, in his trade with the furriers, hatters and cooks, as many as fell into his traps. And in the mistaken idea that all the game found in the wood-district of the former hunting-house of Alba and present hermitage of St. Anna, belonged to the latter, he would have entrapped even the deer and the roes, that were reserved for the Duke, if they had been more abundant, and could have been dug out and smoked out and caught as easily as the fox and the marten, or as that shameless foe of the harmless, playful fishes, the sea-otter.

The sale of the hares and woodcocks to the furriers, hatters and cooks was lucrative beyond our young hunter's utmost expectations. In a few months he had made from

thirty to forty dollars. With this large sum, as it seemed to him, he ran, with the permission of the hermits to Nancy, the city of learning and the arts, some six leagues off. For he had heard that there, more valuable books and in greater abundance were to be bought than in Luneville, where the patronage of the court was more eagerly sought than that of the Muses. For him, every book that could teach him anything, had a priceless value; but what its value might be, commercially regarded, he knew not. A novice in trade, he used, therefore, to lay his money on the counters of the booksellers, begging them to take no more from his poverty than the books selected by him, according to a reasonable, christian estimate, were worth. There was alas! but one among these tradespeople, who honestly resisted the temptation of the money thus offered, and who took no advantage of the unbounded confidence of the inexperienced youth. This gentleman was Mr. Truain, who, born in Bretagne, had established himself in Nancy. He treated the true-hearted lad as a generous friend, let him have all the books he desired at the lowest possible price, and when his money gave out, trusted his honest countenance for several books which he wished. Mr. Truain guessed not at this time that the rustic youth, who stood there before him, would in a few years have in charge the royal library of Lorraine, and would then be in a situation richly to reward his kindness by selecting him as chief purveyor for the same.

Among the literary treasures, which, at this time Duval procured were translations of Pliny, Theophrastus and Livy with notes by Vigenere, and also the history of the Incas, Las Casas' description of the cruelties practised by the Spaniards in America, Lafontaine's fables, Louvois' Testament, Rabutin's letters, and several maps. The books above named, with some others, formed a dear burthen for our hermit in more

senses than one. He had joyfully given all the money he had obtained by hunting for these books, and taken yet others from Mr. Truain on credit. With joy he took the burthen on his stout shoulders and bore it, resting from time to time, on the same day to his hermitage, distant a good journey from Nancy.

The cell which had been given to Duval for his sleeping and sitting room, was almost too small to hold both its inmate and his property at the same time. It now became a world in little, for the ceiling was ornamented with the representation of the heavens, the celestial chart, and the walls were adorned with the maps of the different quarters of the globe.

Among the four old residents of the hermitage, there was one who differed in many respects from the other three, and especially from the gentle brother Paul. This individual, Antony by name, was a native of Bar, whose inhabitants are generally reputed to be easily irritated and quarrelsome. Although he was the oldest in years and the most zealous in the exercises of devotion, he had not wholly conquered his naturally irritable disposition. He was severe and strict in the treatment and care of his own body, and at the same time severe and strict in his judgment of others, so that when he spoke, brother Paul liked best to be silent. This somewhat stormy brother, as the oldest of the little company, exercised a sort of authority over the rest. He perceived with great vexation that Duval was less zealous in the social religious exercises, since he had become so much taken up with books and maps, and that he was employed about things, which appeared to be neither necessary nor wholesome for a pious person. He reproached himself for having lent the young man his compass, and thereby perhaps contributed to his errors, yet he hoped that his admonitions would on that account have more influence with him. As he saw, however, that Duval gave himself up from day to day ever more

devotedly to his thirst for knowledge, he was resolved to get at the bottom of his employments, and so took the opportunity when the young Jack-at-all-trades was absent, to penetrate into his closed cell. How amazed was good brother Antony, when he descried things, such as he had never before seen in the cell of a devotee, and which, therefore, might well seem to him altogether suspicious. What was meant by the celestial globe made of pasteboard with its white and black circles, which Duval had with great pains made to represent the Ptolemaic system; what signified the terrestrial globe prepared of bent hazel-twigs; what were the strange (geometrical) figures and numbers, which the curious Duval had copied and transcribed from a borrowed mathematical book? But more than all these things, brother Antony was horror-struck at a single word which he read upon a large chart of Tycho Brahe's, filled with astronomical figures and calculations. The inscription ran thus: *Calendarium naturale magicum.* . . . "Magicum!" murmured our old hermit full of fright. "Here in a place consecrated to God, will he study magic, that is, sorcery and witchcraft? It must not any longer be allowed."

In the first ebullition of his horror, the old man betook himself to Luneville, to the confessor, a man of distinguished character and learning. To him he gave so strange a description of the pursuits of Duval, and of what he himself had seen in his cell, that the Confessor became curious to look into the affair with his own eyes. Duval, who, in the mean time, had come home, allowed the intelligent father confessor to see and examine every thing in his cell, answered freely every question put to him, and the end of the examination was, that the good father showed brother Antony, with a smile, his ignorance, and the groundlessness of his suspicions, while he commended Duval, encouraged him to persevere, as such learning might sometime be of use.

For a while peace appeared to be restored, but brother Antony could not get over being laughed at on Duval's account by the father confessor. In every look of the free-hearted youth, he fancied he saw a reflection of that reproach, and so he cherished a real dislike of Duval. In this unhappy state of mind, the threat once escaped him that he would tear up the maps and take away Duval's books, a threat, which the blind zealot looked as if he meant to put to execution. To allow these treasures, the possession of which had cost so much care and trouble, to be destroyed—what warm young blood could have endured the thought without violent excitement! For the first, and so far as known, for the last time Duval fell into such a violent rage that he lost all control of himself. As a weapon of defence against such a barbarian assault upon his beloved books, he seized the fire-shovel, and presented himself with such a wild, determined aspect before brother Antony, this imitator of the destroyer of the Alexandrian library, that the old man cried aloud for help. The three brothers, who were at work near by in the field, came to his assistance. The young man, still in fear for his books, drove them with the mere threat of his fire-shovel out of their own dwelling, locked the door, and then watched the movements of the enemy through the window.

It was a fortunate coincidence, that just at this moment the Prior of the Eremites arrived on a visit at St. Anna. He saw and heard the tumult, heard the complaints against the young rebel against the authority of age, but Duval told his story at the same time from the window. The Prior listened with a quietness which restored to the youth his composure, who received the grave reproof which the Prior administered to him as silently as brother Antony received his. Nevertheless, Duval, like a commandant about to surrender his fortress to besiegers, declared that, before the door was opened, he must require security on the following points: 1. An entire am-

nesty for the past. 2. An allowance of two hours every day for his scientific labors, an indulgence which he would relinguish at seed time and harvest. On the other hand, he promised on his part to serve the community of hermits for ten years, simply for board and clothing, with all his powers, and with conscientious fidelity. This treaty was accepted, the doors were opened, and on the following day, the agreement reduced to writing was signed by one party with his written name, by the others with a cross.

Peace was now completely restored among the inhabitants of St. Anna, and with peace flourished again for Duval the usual fruits of peace, the arts and sciences. His inquisitiveness led him indeed, not infrequently in wrong paths, which conducted him to no goal of true knowledge, for with uncommon perseverance he read through works, such as Raymond Lully, several times, word for word, and tormented himself for weeks long to find a rational meaning where no meaning was. The books purchased at Nancy and elsewhere, he had not only read, but as far as it was possible, thoroughly digested. He began to think how he should procure additional nutriment of the same sort. The game of the forest were partly annihilated, and had partly strayed away. While he was seeking some other method of supplying his necessities, a way of obtaining what he wanted, opened itself before him unsought. One day in autumn as he was walking in the wood, pushing before him the fallen leaves with his foot, he saw something shining. It proved to be a finely wrought gold seal, with an uncommonly beautiful coat of arms. Duval, who knew that such armorial bearings often related to family incidents, and who had made himself familiar with the principles of Heraldry, through Menestrier's Introduction, examined the different parts of the escutcheon, without being able to interpret them. On the next Sunday he caused the seal to be ad-

vertised from the pulpit at Luneville, and after a few days, an Englishman, equally rich in outward and in inward goods, presented himself as the lawful owner of the seal. Mr. Forster, so the gentleman was called, had resided some years in Luneville, devoting himself to scientific inquiries and honorable pursuits. Duval was ready to give up the seal, but he first required as a condition, that the meaning of the coat of arms should be explained to him. How this young man, in a poor peasant's frock, should take any interest in such matters, Mr. Forster did not understand. He accounted the request an expression of ignorant curiosity. He complied, however, with the condition of the honest finder, and was not a little astonished, when he perceived, from the questions and observations of the young hermit, that he was thoroughly acquainted with history and its auxiliary sciences, and even with heraldry, and even better skilled in these things than most boys of his age who were taught in the schools. The curiosity of this youth was indeed touching. It proceeded from such a pure, inward longing for knowledge and truth, it received so gratefully what was offered to it, that the kind Englishman, instantly at the very first interview, took a hearty liking to Duval. He rewarded him with a generous sum of money, and invited his young friend to visit him every Sunday and Friday, at Luneville. In these visits, Duval, with his quick apprehension, learned more in an hour than many students in weeks' and months' attendance in the schools, for Mr. Forster had seen the world, he was not only a lover and promoter of science, but was himself versed in history and antiquities. Besides, the benevolent Englishman, was not satisfied with bestowing the spiritual gifts, with which he enriched his eager pupil, but at almost every visit presented him with money.

Thus, all at once, was again opened to Duval a rich source of revenue, not a cent of which did he ever spend on himself

or his clothes, but all went to gratify his thirst for knowledge. As he never went in any dress but his hermit's frock, never, even on his long day marches to the bookstores of Nancy and back, ate any thing but the bread which he took with him, or the food taken by poor people, his library grew to contain four hundred volumes, and among them, since Mr. Forster had directed the selection, works of considerable intrinsic value. In wood and field, by day and partly by night, our young hermit was busy with his books and maps. How thankfully now did he esteem the privilege of having always been employed chiefly in the tending of the cows of the hermitage, just the employment the most favorable to his scientific pursuits. In the quiet of the woods, and in the grotto of the deserted quarry, there was nothing that could distract him, or divert his attention from the subject of his studies. Here he learnt to concentrate his thoughts in a way, that, for his whole subsequent life, gave him an advantage over thousands of others, so called scholars. For Duval read then, not with a divided attention, like others, whose minds are wandering in the most diverse directions among the distractions, cares and pleasures of the world; but his whole soul, all his thinking and imagining, was fixed upon that which appeared to help him to penetrate into the domain of knowledge. The edifice of his knowledge rested not on the sand, but on the foundation of a love, of rare fervor, for truth and a rational apprehension of things.

But in the midst of the still enjoyment of his present happiness, there stirred in the young solitary, a desire that drew him forth into communion with men, into the world. The inward impulse which had hitherto moved him, had not yet reached its resting point. Through the food which he found in books, his wings had only grown and become strong. He would go further and further on. Formerly, when that impulse led him away from the sheep-fold of Clezantaine, did the

wandering herds-boy know, why it was he wished to go forth and onwards? But now he knew more distinctly what the aim of his inclinations, what his true calling, was. He would devote himself wholly to science.

How distant, how unattainable must such an aim have appeared to the poor lad, had he listened only to his own understanding, and not rather rested in the devout faith of his heart! The deliverance from death by starvation and cold, which he had experienced just at the right moment in the sheep-fold of the poor farmer, the happy restoration from severe illness by such strange and yet most salutary means, the childish and yet fortunate device that had led him to Lorraine, the good hand of his God, which here in a strange land had wonderfully led and blest him in all his ways, made it clear to him that his inward as well as his outward life was under a Providence that knew how best to complete every work that it has begun. This Providence had supported him in scarcity and hunger, had provided for his body, on his painful wanderings, shelter and aid; why should it not also furnish means to allay the hunger and longing wants of the mind, which it had itself formed and nourished?

Amidst these thoughts, Duval felt like one who crosses over a deep abyss upon a narrow trunk of a tree, and dares not look down into the depth, lest he should become dizzy. For ten years' service for board and clothes, he had bound himself to the hermits. At the end of this time, he would have as little money for books as he had now. His honest heart could imagine no possibility by which that written contract could be cancelled. Nevertheless, this thought caused him no care or trouble. When he meditated over the many years which must elapse before the agreement was fulfilled, they seemed to him but as so many days. It did not occur to him that he would be older also. His entrance into a school or

college, where he could form himself for the calling to which he felt himself destined, appeared to him as a thing that would happen of itself, and prove as easy as his journey from Champagne to Lorraine, or from Clezantaine to La Rochette. His vivid imagination represented that, which was yet distant, as if it were to take place to-morrow or to-day. The hope of a youth is like a good powerful telescope, which brings the distant object so close within the sphere of vision, that it seems as if one could seize with his hand the mark, which a ball from a gun could hardly reach.

In such a happy state of mind, knowing nothing of to-morrow and its sorrow, but only of to-day and its plays, a certain beautiful spring morning, in the year 1717, found him lying on the ground in the wood with his out-spread maps, studying them with the greatest attention. Suddenly, he heard a man's voice which bade him good day. He looked up and saw a gentleman, on whose countenance a noble dignity joined with gentleness was expressed, and who asked why he was here so busy with the maps. "I am searching for and considering the way," said Duval, "from the coast of France to Quebec in Canada." "To Quebec?" asked the gentleman further. "And what have you to do with Quebec?" "I have read," replied Duval, "that there is a French Seminary or High School there, where many good things are taught, and where the children of poor people are received and instructed for nothing, and, therefore, I am thinking of traveling thither, to study in Quebec." "Indeed!" said the gentleman, "to learn something good, and thorough, one need not go so far; free instruction for young people, who have the will and the talent to study, may be had here too in our Seminaries and High Schools."

During this conversation, several other gentlemen had approached Duval, whose dress and bearing showed them to be

persons of no common rank. They asked the High Steward, Count von Vidampiere, for this gentleman it was, who was talking with the young hermit, about the subject of the conversation and the remarkable boy with whom he talked, and then addressed several questions to Duval, which he answered with propriety and a noble openness. He dreamed not of what importance, of what consequence for his whole life, the examination would prove, to which he was then submitting; and perhaps this ignorance was to his advantage, for thus his sound understanding, his wit and good humor, the wonderful extent of his reading, (his station in life considered) were manifested with that freedom from constraint which rendered them all the more pleasing.

The high assembly, in the midst of which an examination was held, which, for this time signified more than any doctor's examination in Paris or London, consisted chiefly of persons from the court of Lorraine. The two young princes, Leopold Clement and Francis, together with their high officers, Count von Vidampiere and Baron von Pfutschner, represented the examiners, who proposed questions to their candidate in a boor's frock, and received from him answers by which a young school-educated pupil could hardly have gained greater honor than Duval, the nursling of nature; for in the simplicity of his whole manner it shone forth that he uttered nothing that he did not truly feel and honestly believe.

Baron von Pfutschner, the tutor of the two princes, asked Duval whether he would like to continue his studies in the school at Pont a Mousson. Duval inquired whether in that establishment, which resembled a monastic institution, liberty would be granted to go out into the woods and fields, for he could not always remain in doors. They satisfied him on this point, and at parting the Baron promised to visit him again shortly.

On returning home, the princes told their father, the mild, humane Duke Leopold, what strange game they had met with in their hunt, in the acquaintance they had made with a young cow-herd who had astonished them all by his knowledge of geography and history. It required but a few words to win the good Duke to the plan, of which the baron had spoken. His Grace consented that Duval should enter the institution of Pont a Mousson at his expense, and be maintained there so long as was necessary. At the duke's expense also, he was to be clothed and liberally provided with whatever might be required for his residence there and for the advantages of his education.

Duval was now twenty-two years of age. Now, in May, 1717, it was almost eight years, since, as a poor boy, he had come to Lorraine in wooden shoes and dressed in coarse sackcloth; four years had passed since he entered the service of the hermits of St. Anna as a cow-herd.

With the thought of quitting St. Anna, now so dear to him, and its friendly inmates, he felt for the first time in all its strength what he had here enjoyed and received. He had communicated to the brethren the strange adventure he had met with in the wood. They congratulated him, but also, in their simple undisguised way, gave him to perceive their regret at their probably near separation, a regret awakened by their truly hearty love for their young friend. Here brother Antony was not behind the rest. The love was without hypocrisy, with which, he silently and with a tear in his eye pressed Duval's hand, and urged upon him as a gift, the only scientific treasure which he possessed, the pocket compass. In such violent natures as brother Antony's, the Creator, together with the repulsive characteristic which not unfrequently breaks forth in them, implants in like measure an opposite and attractive capacity of love; so that oftentimes, when a warming sunbeam from above falls into the darkness of their hearts, their hatred

grows into fervent love. This excitable power resembles in its working the wine which, in good hours strengthens the soul to noble deeds, while in evil hours it hurries it to its fall; but at all times it brings with it its dangers.

The school-rooms, in which we usually receive instruction, are at one time too cold, at another too hot; the dampness of their gray white walls seems as if it would symbolise that anxious perspiration which we suffer in those confining spaces. When we would listen to the instructing words of the teacher, our next neighbor on the school-bench is pulling or pushing us, another is coughing, a third whispers in our ear or speaks two or three words to us on a bit of paper; outside is spring or lovely autumn weather, and we sit and perspire there within four walls. With a more than unusually awakened sympathy we then learn, how formerly Plato, and Aristotle, and Theophrastus inspired their hearers with their eloquence in the open air, in the shade of porches and of trees. In after years one thinks, perhaps with pleasure, of well-spent school-hours, and blesses with grateful love the memory of beloved teachers, but cares not to dwell on the recollection of the black or white benches, on the dingy stoves and walls of the old school-rooms. They had not the fragrance of the woods or of the green fields which the Lord has blessed.

Quite otherwise was it with Duval. The sublime stillness of nights, only rarely broken by the sounds with which the owl and the bittern accompany their labors, the silence of the woods, and the refreshing air of their shades, must needs have had another charm for memory than our buildings with stoves and chimneys. The voice of instruction which we receive through the outward ear, had been to Duval an inward voice, and on that account, penetrating the more deeply into his soul. With such tears as we shed, when we embark on the broad ocean and bid farewell to the shores of our fatherland, Duval

looked once more on his seat in the high oak, so like a stork's nest, where the rolling stars of the night awoke in his breast the aspiration for an infinite and eternal world, surrounding us everywhere. With similar emotions he took leave of the grotto in the old quarry and of every old oak or beech, in whose shade he had been at school to the invisible and yet present teachers of ancient and modern times.

Baron von Pfutschner had not forgotten his promise. Only a few days elapsed since his acquaintance with Duval, when he came, according to the custom of the time, in a coach and six, and took the young hermit with him to the Residence. He had passed his examination with success. Now he was to be promoted in the presence of the Duke and a number of ladies and gentlemen of the court assembled out of curiosity. Here also our Duval bore himself with honor. Here were no such dangers or pains to be feared as in battles with wild cats or with biting foxes and weasels. He spoke and answered with child-like openness, and his remarks gave at least as much cause for admiration as for amusement. They found the peasant youth beyond all expectation intelligent, and in his way, amiable. Some ladies, who after the promotion, on which the gracious assurances of the Duke had placed the crown, fell into conversation with Duval, admired his white teeth. "It is only an advantage," said the honest lad, "which I have in common with all dogs."

Duval, the history of whose youth is adapted above that of all others, to disclose to us the inborn instinct of the human mind in its whole force and activity, had now arrived at a resting point, beyond which his career becomes less remarkable and unusual. Like a river, which has its source in a rocky, mountainous region, and at the beginning of its course delights the eye with many a picturesque waterfall, but which only when it descends into the plains, where its flow becomes quiet

and scarcely perceptible, spreads abroad its blessings through fields and meadows—this remarkable man became note-worthy, on his entrance into the world, more for his influence on the fortunes of others, than for the changes of his own. The kind Duke Leopold took him into his special favor, advanced him a year's income during the two years spent at Pont a Mousson, and afforded him opportunity to visit Paris and the Netherlands. And to such a lover of books as Duval was, what office could have been better adapted and more agreeable than that of librarian, to which, upon his return to Luneville, he was appointed by the Duke. He was at the same time appointed teacher of History and Antiquities in the high school at Luneville. This institution was at that time the resort of many foreigners, particularly of the sons of rich English families. Duval's instructions were, from their vividness and originality, so attractive, the whole manner of the man inspired such love and confidence that he exercised a very great influence on the young. Among the young Englishmen, who, not only took the deepest interest in his public instructions, but also delighted in his society, was one, of whom Duval prophesied that he would act the no inconsiderable part which he afterwards took in the affairs of his own country. This was the statesman afterwards so celebrated, the English minister, Lord Chatham.

For the supply of his own wants, our former hermit needed very little. In the place of all other pleasure, the delight of an occasional visit to the quiet and lonely woods and fields, ever remained the dearest to him. The country was more beautiful to him than all the splendors of Paris. He could never bring himself to give up the retirement and independence of a single life. His scholars and the poor were his children. A faithful friend, of similar tastes and fortunes, gladdened with his society his hours of study. This friend was Mr. Varinge, whom the noble Duke Leopold had taken from the work-shop,

in which he was found with a Euclid in his hand, and gave him opportunity to qualify himself as a teacher of mathematics in Luneville.

One portion of the considerable property which Duval possessed through the liberality of his prince and his wealthy pupils, he devoted to acts of pure gratitude for those early favors, the living remembrance of which never forsook him. Especially did he remember his beloved St. Anna. Instead of the decaying wooden dwelling of the hermits, he caused a respectable stone building with a chapel to be erected at his own expense, and at the same time purchased a considerable tract of land, which, divided into pastures and orchards, afforded abundant support to the brotherhood. To the new arrangements which according to his plan were made at St. Anna belonged a nursery of trees. In regard to this he directed that the hermits should devote themselves to the culture of trees not merely for themselves, but also for their neighbors. They were required to furnish young trees gratis from their nursery to the inhabitants of the country round to the distance of three leagues from St. Anna; and if it was wished, to set out the same for nothing. They were not even to accept anything to eat, unless the distance was too great for them to go home to dinner. A capital of thirty thousand francs was in this way bestowed upon St. Anna, which long afterwards, particularly by the cultivation of trees, yielded a large income.

Two miles westward from Nancy at St. Joseph of Messina's, there still lived in a hermitage, built by the before-mentioned brother Michael, the aged recluse who had formerly taught Duval the art of writing. His hut was so ruinous, that it threatened to go to decay before the frame of the old man that bowed with the weight of ninety years. Duval, out of gratitude, caused a house to be built for this aged man and his successors, which, by its respectable exterior and its inward con-

veniences, stood in as striking contrast with the beautiful country as the decayed hut. His birth-place also, Artenay, and his yet surviving relatives received rich tokens of his generosity. Instead of the poor dwelling of his parents, which had passed into strange hands, he built a spacious building whose stone walls and tiled roof contrasted strongly with the thatched clay hovels of the barren landscape. This building he presented to the town to be used as a school-house and a residence for the teacher. A little village not far from Artenay, stood in need of a fountain to the great distress of the inhabitants. Duval caused a well to be dug; and if the poor tenant, who had taken him into his sheep-fold in the winter of 1709, as well as the good pastor of the place, had still been alive, the gratitude of their former nursling would certainly have been manifested towards them.

Duval had, in his first wandering into a strange land, given himself up to an instinctive impulse which was to him, as he thought, into the country nearer to the sun, upon which the winter could inflict no suffering so severe as that which visited his own poor fatherland in 1709. To the east and the south, so had he been told, these regions, favored by nature, might be found, and his former course from west to east had confirmed his previous opinion, and moreover had had happy consequences for his whole life. The force, however, which led him, in his forty-second year, from his beloved Lorraine, at the beginning of his course, towards the south, but afterwards to the east, to a residence as pleasant as Luneville had proved to be, was different from the first impulse, which resembled the natural instinct of a hungry animal. The father-in-law of the French King Louis XV., King Stanislaus of Poland was to be indemnified for his lost throne; the influence of France and the powers in alliance with her, compelled the reigning house of Lorraine to an exchange, which, in many respects, was no

disadvantageous one. The Duke of Lorraine was required to give up his throne, (which was in fact continually threatened by the unquiet and dangerous neighborhood of France,) for the government of the rich and beautiful Tuscany. Sorrowful as was the separation on both sides, of the Duke from his subjects, and of his subjects from the Duke, the forced exchange took place in 1737. Duval's paternal friend, Duke Leopold, had died; his successor, Duke Francis, set out for Florence, and Duval and his friend Varinge, allowing no foreign offers to prevent them from remaining faithful to the Ducal house, to which they owed all their success, departed with the Duke for Italy. Duval held the same office at Florence that he held at Luneville. When a few years after, the Duke married the heiress of the house of Austria and went to Vienna, and when shortly afterwards Duval's most intimate friend, the mathematician Varinge, died, beautiful Florence lost all its charms for Duval. He gladly obeyed the summons of the Duke, who had attained to the imperial dignity, and became the founder and first superintendent of the imperial collection of coins at Vienna. Solitary and unpretending, Duval lived and labored at the Imperial Court. His investigations in the whole circle of knowledge grew ever more earnest. His mind was emancipated from all the prejudices which could obstruct his progress. All his energies, his whole property was at the service of his neighbor. He lived to a serene old age of eighty-one years, retained full command of his faculties to the last, and departed upon his journey into the world beyond the grave as cheerfully and with even better hopes, than when he set out in his boyhood from impoverished Champagne for the beautiful, peaceful Lorraine.

PART II.

THE FORE-COURT OF THE KNOWLEDGE OF NATURE.

11. THE GETTING RICH WITHOUT TROUBLE.

How must the good Duval have labored merely to obtain that, which every city-child learns at school; how many sleepless nights did it cost him, before he could understand what and where the constellations are, and what the degrees on the equator of a globe mean! Worthy persons of the same stamp with Duval, who earn the treasure of their knowledge with difficulty and have to dig it out of the depths, may be likened to those well-to-do-people, who, leaving home poor, accumulate property by their own diligence and frugality, while we, to whom every thing comes at school that can gratify our desire of knowledge, resemble those who have never earned their wealth, but inherited it from rich parents.

How much harder than to Duval and his friend Varinge is the supply of the thirst for knowing, implanted deeply in the soul, in case of those who lack, perhaps from birth, that sense which furnishes us the most information respecting the world of knowledge, the sense of sight. But this difficulty is unquestionably greatest in the case of those individuals, so much to be pitied, who like Laura Bridgman, are wanting, not only in the sense of sight, but also in hearing, smell and taste. Duval, when, like the builders of the tower of Babel, he sought

to penetrate into the starry heavens by building his stork's-nest on the high oak, saw indeed those shining worlds with his eyes, and every ray of the same caused him to feel something of their power in himself; but when the poor Laura read, with her finely-feeling fingers, in one of the books printed for the blind, something about the stars, how would she be compelled to task all her powers to the uttermost, to form an idea of the nature of things which she had never seen! And yet, in such cases, her efforts were never wholly without result and reward. The essential nature of what is capable of being known, the mind of man may apprehend, without having any knowledge of it, obtained through the senses; the impulse towards knowledge in the mind is ultimately directed to something which is of the nature of the mind; the aim of its endeavor is a certain confirmation of that, which it hopes for and inwardly apprehends, even without seeing it with the external eye.

The blind mute, James Mitchell, had a great advantage over Laura in this respect, that he not only possessed very acute senses of smell and taste, but that a faint glimmer of day-light still penetrated his organs of vision. What curiosity, and what delight in knowledge was often times expressed in all his looks and gestures, when he changed his position for one, in which a ray of the sun fell directly upon that point in his eye, not entirely closed against the light, and when, by means of a piece of looking glass he could catch the reflection of a sun's ray on that point, or could bring a burning light into the neighborhood of his eye. A devoted friend of Astronomy can have no greater pleasure, when the telescope opens to him an entrance into the mysterious depths of the starry heavens, than James felt, when for him likewise, a faint ray broke into his perpetual night, from the world of perceptible things that was shut against him. The more entirely cut off and lonely the situation of the mind is, in relation to the external visible

world, the more eagerly does it seize at every thing which comes within the range of its recognition. The companions of the celebrated Parry, on his voyage to the polar regions, gazed at the water-fowl flying over them with the curiosity, with which we, perhaps, look at a rare animal from Africa, because upon the great floating ice-islands, over which they drew their sledge-boat, there was no other living thing to be seen. A man, who is placed alone upon a desert island, looks curiously at every little wave of the sea that rises above the rest, because in every such appearance, he fancies a ship that shall bring him tidings from the world of other beings.

The greater the distance, through which a falling stone has to pass, before it finds its firm resting point on the earth, so much the more rapid and powerful is its descent; when part of a mountain falls, those pieces of rock roll the farthest, which descend from the greatest height. Thus, in such cases as are presented to us in the histories of the intellectual development of Duval and Laura Bridgman, we cannot but see plainly that precisely the great obstacles, which the intellectual impulse has to overcome, give to that impulse a quite peculiar and unusual force. But that impulse urges every human being; we all have a natural desire of knowledge, whether the satisfaction of this desire be made easy or difficult. To us, indeed, in comparison with Duval, and still more with the blind mute Laura, it is given amidst the many means of obtaining knowledge placed within our reach, to get rich without great trouble; but should we, on this account, because it is made easy for us, leave those means unused?

I think not. It is good to get and to gain; and if we neglect the opportunity thereto, it must be, that we regard ourselves as already rich and satisfied, not as needy, while, however, it is hunger alone which gives to the food of life its relish and its nutritiousness. I hope that the following pages, which

like little cups or dishes are to offer various viands to the desire of knowledge, may awaken in many a young mind, a desire to help itself, and an appetite to partake of the feast.

12. THE ALMANAC-SIGNS.

When Duval, in his younger years, while still at service in Clezantaine as an ignorant shepherd, took up the Almanac, which always gave him so much to think of, his curiosity was often excited by those signs, which mark the sun and the planets as well as the several days of the week. That the moon-sickle represented the moon, and among the days of the week, Monday, and the circle with a point in the centre, the sun, and in the week, Sunday, soon became known to him. The evening star and the morning star, these too his employment as a herds-boy soon brought him acquainted with, and, at the same time, he learned that the little circle, which has a cross below it in the Almanac, represents these stars. Before, however, he learned to know the other more remarkable planets, Jupiter, Mars, Saturn, and their signs in the Almanac, a long time elapsed.

The insatiable curiosity of Duval did not permit him, as we have seen, to stand still with the knowledge of the constellations. Soon he wished to know how our earth looks, what is its size, and what lands and seas it consists of. Could the eager youth have had a look at such a globe as Charles William Kummer made in Berlin, (a relief-globe) on which all the elevations and depressions, the mountains, vallies, and plains, are represented, with what delight would it have filled him! How at once would much have become plain, over which he long racked his head in vain. But such beautiful helps to learning, as are now so richly provided for the young, were not to be found then even in the school-rooms of royal princes.

Even with the study of Geography, although as long as he lived, it was one of his most favorite employments, the inquiring mind of the young hermit was not satisfied. He procured books of the most opposite kinds, and precisely those, whose contents and language were the most mysterious and dark, excited his curiosity the most; with an admirable perseverance he tormented himself in trying to understand the writings of Raymond Lully, a celebrated scholar of the middle ages. In such books of the same period, which, by their pompous titles, and by their prefaces, promise to introduce the reader to all the mysteries of nature,—the case especially with the works that treat of chemistry (then styled Alchemy,)—one finds the same signs again, which in the Almanac represent the sun and planets, but here they are used very differently. For what in the Almanac stands for the sun, in those writings represents gold; the signs for the Moon, Venus, Mercury, Mars, Jupiter, Saturn, are by the old chemists used to denote silver, copper, quicksilver, iron, tin and lead.

We should not regard with entire contempt these double signs of the almanac-makers and the chemists. They merit a certain respect for their high antiquity; for they have passed through the hands of many people, and through a long line of centuries, ere they have reached us and taken their places in our almanacs. Astronomy is a primeval science. To the earliest fathers of our race, who, in mind and body enjoyed the health of youth, who were not then distracted by the thousandfold influences of our modes of life and the daily tidings of the press, but lived in still communion with nature like Duval, the herds-boy and hermit,—to them it happened as to him: the thirst for knowledge which was in them, turned first, above, to the starry heavens. As children, so soon as they can move their heads, turn most eagerly to the light and the moon, and

struggle joyously with their little hands, when they see anything shining, so also was the curiosity of men in the earliest times, attracted most powerfully by the shining stars of heaven and the glittering stones and metals of earth.

When Duval had become acquainted with the lands and seas on the surface of the globe, how gladly would he have learned still further what is known of that which is hidden in the depths. When an Indian or a poor boy takes in his hand for the first time in his life, a watch, and has for a long time wondered at the moving of the hands and the ticking of the mechanism, he would next gladly know what is inside the watch, and he often gratifies his curiosity to the great detriment of the work. So is it with the desire to know, which moves the human mind. It seeks to penetrate the depths as well as ascend the heights of all visible existence. Man seeks to know not merely *that* a thing is, and *how* it is, but he also inquires, *whence* and *by what means* it exists.

But to return once more to the almanac-signs, which have the double signification of the stars of heaven and the metals. The interest which man takes in the metals did not arise accidentally from the use which could be made of them, or from the value gradually attached to them in exchanging them with other things; but that interest may have been created in another, natural way, which it would lead us too far aside to explain. Physicians and other observers know that the metals have a certain influence upon the internal organs of sensation (the nerves,) and that in many conditions of disease, the attraction of metals is so great that the individuals afflicted are aware of the vicinity of metals, even when they do not see them. In such cases, it has appeared that some metals, especially gold, have a beneficial, while others, such as iron and zinc, exert a disagreeable, painful influence. The morbid affection for the

metals, which we justly condemn as avarice, finds no excuse here, as we can in some degree understand the external cause of it, whence it proceeds.

We are speaking here, however, not of the relation in which the metals directly stand to the physical nature of man, but only of the relation they bear to the advancement of our knowledge of visible things. And in this view it may be said that these shining bodies, which do not indeed give out light of themselves like the sun, but like the planets, like the beautiful evening and morning star, powerfully reflect the light received from the sun, are as important to a knowledge of the earth as the celestial bodies, whose signs the science of antiquity has impressed upon them, are to Astronomy. The metals belong to those truly simple elements, out of which the terrestrial bodies of nature are composed; their examination prepares the way for us to a knowledge of the elements strictly so called. And, instead of directing our curiosity upwards to the stars, let us take the opposite path in the first place, downwards, to the elements of our earth, and then, from a firm foundation, we shall be able to ascend all the more successfully.

13. THE ELEMENTS.

The ancients recognised, as is known, four Elements: fire, air, water, and earth. Of these original substances, according to their opinion, all material bodies are formed. With our present scientific modes of speaking, the idea of four elements in the sense of original substances, is no longer admitted, for our chemistry has brought us acquainted, not with four, but with fourteen times four original substances of material bodies;* and that which we name, earth, according as we make a trial

* There are sixty-two Elements known at present.

of it here or there, is composed of a greater or less number of substances; water of two; atmospheric air, when we take into view the vapor usually existing in it, consists of at least four substances. And with the three so-called elements, definable by weight and measure, the fourth, fire, is classed with as much propriety as virtue would be, if it were ranked with three articles of food or furniture, or if, with our present ideas of original substances, one should number fire among them, it would be as if he were to say that the human body consists of bones, flesh, skin, and *motion*. For fire is not, in the ordinary sense, a substance, but it is, in its nature, a motion of substances, as the tone of a piano-string, which the ear perceives is not brass wire nor air, but a motion of the stretched wire and of the air, whose agitation acts upon our organs of hearing.

However, with our present insight into the nature of simple substances, we must not too severely condemn the ancient division of the four elements. There lies in this division a deep truth, as we may perhaps hereafter see, when we have first explained what is to be understood by simple substances.

14. SIMPLE SUBSTANCES.

A statue of marble, fashioned after the likeness of the human form, contains neither veins, nor flesh nor bones, but when an accident or a barbarian hand breaks it into pieces, we find in all parts of it, from the head to the foot, from the surface to the centre, everywhere in and on it, nothing but white, granulous limestone or marble. When we break it into still smaller pieces, it remains everywhere and throughout the same; every grain, like the whole, is a white marble, and, examined by a powerful microscope, there are seen in the grain the same surfaces, the same brightness, the same colors that appear to the naked eye in a much larger fragment.

Nevertheless, the innumerable particles and grains, into which the block of limestone, to which the artist has given the human form, is broken, are by no means the substances of the mass, but every one of those grains is composed of several substances. That this is so, every lime-burner knows, when he puts the marble into the fire. The lime loses then the water and carbonic acid with which this earth was combined, and this remains, as so-called pure calcarious earth or quick lime. But even this earth is no pure substance, but, as the further investigations of later times have shown, consists of a metal and a substance of atmospheric air, of which we shall soon have more to say, oxygen gas, or vital air.

Vermilion, that beautiful, red, coloring material is known to every one conversant with painting. When by rubbing and bruising, a piece of vermilion is reduced to a powder, every particle of the same remains what the whole was, vermilion. But if one mingles with this triturated vermilion a quantity of iron filings, and exposes this mixture to heat, two different substances are immediately disclosed, sulphur and mercury; for the sulphur, which has a stronger attraction for the iron than for the mercury, combines with the iron, and makes sulphuret of iron, and the mercury is set free from its previous combination.

The copper, from which a portion of the Russian copper coins, called kopecs are made, comes from the rich Ural mines, and often contains in its combination a certain proportion of gold. Copper of this kind, which is found also, particularly in Japan, is distinguished from common copper by its beautiful red color, and great ductility, but when a bit of it is pulverised ever so finely, still every particle contains the same mixture of copper and gold as exists in the original mass. When, however, sulphuric acid, diluted with water, is put upon it, the copper is separated from the mixture, which becomes blue vitriol,

and the gold remains as a fine sediment in its metallic purity, and may be melted back again into a combined mass.

In all these cases we observe that there is a two-fold force that brings together and unites the smallest parts or atoms of bodies. When birds of passage, moved by a common impulse, set out upon their far journies, they collect in great multitudes. In spring too, before the time of pairing has arrived, they still keep together in large flocks. But when the time to build their nests has come, then the great masses separate into families. The natural instinct, which is the basis of this union by pairs and of the tender care of the young, is much stronger than the gregarious impulse, and the latter can only avail, when the stronger instinct releases the individuals from its ties, and then the power of that universal world-life seizes the flocks of individuals, and converts the union of individual beings into a union for the spaces and regions of the earth.

In a similar way, a universal attraction works in the union of the homogeneous parts of vermilion or of the gold mixed with copper; but in the union of the sulphur with the iron, or of the copper with the vitriolic acid, a peculiar and stronger attraction is the universal force. The power of cohesion, which causes the more or less firm connection of single parts, is of like nature with that universal attractive force, which, as gravity, unites the single masses of physical bodies into the globe. It may be neutralised by what are called mechanical means, as when, for example, a large stone by the force of its gravity crushes another and smaller one, or when the pressure, caused in this instance by gravity, is produced by the force of man's arm, or by his art. Chemical relationship (affinity) is based upon that polarisation (sexual opposition) in which the special life and creative working of things every where has its beginning, because it proceeds from the very source of life and creation (ch. 8.) The power of cohesion has for its end and aim

the preservation of things as they are; chemical affinity, on the other hand, a new formation. We have not yet arrived at the explanation of what is to be understood by simple substances. To this end we must make an apparent digression by considering more closely the metals.

15. THE METALS STRICTLY SO CALLED.

Could we transport ourselves at once away from the earth to those great spaces, which separate our globe from the sun and its planets, we should find there, at mid-day no day-light. For here, upon the surface of the earth, the light of the sun is reflected from all bodies, even from the air, as the morning and evening twilight shows us, whose light comes merely from the atmosphere before the tops of the mountains are illuminated. But there, in the planetary spaces, there is neither air, nor mountain, nor any other body to reflect the sunlight and thereby diffuse in all directions the light of day; for if the planetary spaces were capable of such reflection, we should never have complete night upon the earth. On that account, the human eye, turned in that immense space towards the sun, would see it as a bright disk standing on a dark, black back-ground, and when turned in an opposite direction, it would see the stars upon the same dark ground. The beneficent, illuminating, warming influence of the sun can make itself manifest only when it meets bodies, which, by the polaric variation of their whole being from that of the sun, are the most susceptible of such an influence, especially such bodies as unite the greatest solidity with opacity.

Such bodies are especially the metals. In themselves devoid of light, and more than any other bodies, of heat of their own, they are, on this account, susceptible of being affected by light and heat; but not only by light and heat, but also by all

the other powers of material life which are awakened by polarity, by magnetism and chemical affinity. The collected stone-masses of the mountains, which we see around us, have proceeded, in their formation from a condition, originally metallic; a metallic substance is their basis, which, united with the universal opposite of metallic natures, with the oxygen gas of the air, then becomes a kind of earth; the first movements of a self-dependent formation and fashioning take their beginning in the kingdom of the metals.

The sun in the heaven has in the terrestrial material world its opposite sun, in *Gold*. Its remarkable color, its great brightness, showing itself on the rude surface of a lump of the metal by a slight polish, its great weight, its pliability, (malleableness and ductility) under the hand of man, must have attracted attention to it in the earliest times. Gold was at first much more easily obtained than in our days, and it was wrought with much more ease than iron or copper. For only by a high degree of heat can iron be melted out of the ore, in which it is found, not in a pure state, but mixed with other substances, while gold, on the contrary, came to hand in full purity, and might be hammered and wrought just as it was; the heat, required to make it fluid, is a great deal less than that required by iron. Besides, gold invited men to its use by the way in which it presented itself. For, although this precious metal was originally, like other metals, enclosed in rocky substances, yet by the crumbling to pieces of its original beds, it came to be found among boulder stones, and the sands of vallies and plains; and then its pliability saved it from being broken and crushed, while its peculiar gravity prevented it from being as easily washed away as the stony fragments and sand in which it lay bedded. The man, therefore, who came upon a rich spot of this sort, frequently found gold in lumps of considerable size, lying open to the day, or when, in the course

of centuries, turf and forest had spread over a stone or sand field originally rich in gold, the discovery of the treasure was soon made, in the digging of a ditch, or by any other process which was calculated to expose the gold. In a way similar to this, the gold riches of a large, sandy surface in the Ural mountains in Russia, remained undiscovered until some years ago, and then a significant idea could be formed of what the ancients say of the gold wealth of India and Arabia, and modern writers tell us of South America. In that Ural gold district was found in the year 1825, a lump of gold weighing eighteen pounds, and nine other pieces, each of which weighed several pounds. At Miaesk, in the government of Orenburg, a lump of gold was found, seven pounds in weight. Although these masses are not to be compared with that piece of gold which was discovered in the year 1730, in Paz, in America, which weighed forty-five pounds, and out of which five thousand six hundred and twenty ducats were coined, nor with that again, dug up at Bahia, in the Brazils, in 1785, whose weight was two thousand five hundred and sixty pounds, and which was estimated in money-value at also a million and a quarter of guilders, yet the lumps of gold found in Russia were the most considerable, so far as history informs us, ever discovered in so northern a region. For when we consider what the ancients tell us of India or Ethiopia, or of the gold of Arabia, which was found in pieces of the size of a chesnut, and what is told of the masses of this metal found in hotter America, we come directly to the opinion that the countries between the tropics, or in their neighborhood, are the almost exclusive home of Gold.

Gold, even in the countries in which it is most abundantly found, is indeed, in comparison with other metals, a rarity. For although the amount of gold obtained yearly for the last three centuries from the rich Spanish and Portuguese possessions in America may be estimated at something more

than a hundred and fifty cwt., yet this is not even the hundredth part of the silver which these countries produce in the course of a year, and, if we take only one country into the account, not the thirteen hundredth part of the amount of the copper, scarcely the sixteen hundredth part of the lead, nor the three thousandth of the iron, produced every year in the comparatively little country of England.

On account of its rarity, but yet more for its other advantageous qualities, this beautiful and shining metal has, from ancient times maintained a value in exchange and trade, which exceeds about twelve times that of silver, indeed in our days somewhat more than fourteen times. If one of us were to find upon a desert island, or in fishing in the sea a lump of gold, so heavy that we could not carry it a league without great exertion, he would have enough for himself and his for his life time, for every pound of gold is worth four hundred and fifteen Prussian dollars or seven hundred and twenty-seven Rhenish guilders.

Nevertheless, let us mention in passing, there are some things to be considered in regard to finding a prize of this sort. There is something tempting and perilous in thus getting rich without trouble. In the eleventh and twelfth centuries many people in Bohemia set to work to wash out of the sand of one of their rivers the gold contained therein. Many of them gained more than could be got then by agriculture and the raising of cattle. But what happened? When the other inhabitants of the country saw that hundreds and at last thousands earned more by this easy business than they with their hard labor, many of them, thinking they could do as well as others, left their land untilled. There arose a great scarcity and severe famine in the land. Of what avail was their wealth then, to the most fortunate gold-washers, who in a year's space had procured a pound and more of the noble metal? They could not for hard money

purchase bread enough for themselves and their families; many perished of starvation, and the government, in order to prevent the recurrence of similar unhappy consequences, forbade the business of gold-washing under heavy penalties. (M. v. Hagecius in his Bohemian Chronicle, translated by Sandel, p. 329.)

And has not that, which then impoverished a little country and its inhabitants, been repeated also on a grand scale in the history of mighty kingdoms? In our days what has poor Spain, what has Portugal kept in actual possession, of all the thousands of hundred weight of gold, which they took from the harmless people of Peru, from the nations and rulers of Mexico and Brazil? To what heirs did the wealth of the Sultan Ackbar (the Grand Mogul) who died in 1605, descend, amounting in value, chiefly in silver and gold, to three hundred and forty-eight millions of guilders?

Among the European powers Russia stands next, whose gold gains from the Ural mines were estimated from 1814 to 1824, at twenty-four millions of Prussian dollars. Austria, from its mines in Hungary and Transylvania chiefly, obtains a yearly average of four thousand seven hundred marks (sixteen half ounces each,) from Bohemia twenty-three, from Salzburg about one hundred and sixty-five marks. France obtained formerly, especially from its gold-washing in Languedoc, about two hundred marks. England has indeed no gold mines. Since the abolition of the slave-trade she receives from Senegambia over three thousand four hundred marks, and her iron and steel fabrics, exclusive of all other sources of profit, bring her a larger income than Portugal and Spain formerly obtained in pure gold from their American possessions.

We have here, in our consideration of the metals, been drawn away as it were by the attraction which gold has for our human nature. We are still, however, on the path which

leads to our proposed aim, the consideration of what simple substances consist in.

More than any other material body, gold is adapted to show us what an original substance or element, incapable of being further decomposed by chemical action, is. An element, by its combination with other elements, may furnish the ground-work for other products of nature and art; but to its own origination, it needs no element but that which is actually its own; in all the combinations into which it enters with other bodies, it always remains the same and comes forth again unchanged and ever the same out of such associations.

How entirely different is it with those other natural bodies which are not pure substances. Vermilion or sulphuret of mercury, and galena or sulphuret of lead, when crushed by mechanical force, seem to remain the same even in their smallest particles; under the microscope one sees in the dust of galena, the same cubic forms and shining surfaces which are present to the naked eye in its larger masses. But when the two bodies, the vermilion and the galena are exposed to a certain degree of heat in company with iron, then the appearance of simplicity soon vanishes, for, in the former, the sulphur forsakes its connection with the quick-silver; and in the latter it separates from the lead and unites itself with the iron and becomes sulphuret of iron. It is apparent that these two bodies are not simple substances, but only combinations of substances.

When men began to use gold in buying and selling in order to obtain articles the most various, and learned that for gold all the gratifications of the senses could be procured, they strove all the more eagerly to possess this precious metal. In the course of time gold ceased to be found in its beds of boulder stones and of sand, which had been examined in all directions.

It had then to be melted out from its peculiar birth-places—the mountain rocks. Men knocked, therefore, at every stone, exposed all sorts of stones to a melting heat, to ascertain if perchance any gold were hidden therein. There was not then as now any need to be sparing of fuel when whole regions were covered with primeval forests. Smelting-furnaces, those little types of volcanoes, men learned early enough to build, and the earliest nations, like our children now, soon found a special pleasure in melting stones which contained metal, and which were to be distinguished chiefly by their weight. By these experiments very soon all kinds of metals, tin, zinc, and even copper and iron, were obtained from stones, which possessed a quite different form and color from that of their metals. And by further experiments it was found, for example, that from the melting together of zinc and copper, brass arose, a metal, which, in color and brightness, has a certain resemblance to gold. The question next arose, whether gold also could not be made, either by the discovery of a body which might be changed into gold, like calamine into zinc, or by the admixture of another and more easily procured metal with some other substances.

The noble gold has in its way many qualities in common with great and noble minds, namely, patience and gentleness. Without losing its composure, that is, its peculiar material cohesion, it allows itself to be drawn out into wire, and to be beaten into leaves, like no other body. The Nuremberg goldbeaters have a saying that with a ducat one may guild a rider and his horse. While it bears itself so gently and yieldingly to the cutting knife, gold lets itself be bent and drawn like no other body in nature. For this reason, it has never lost its equable bearing under any experiments, to which doubts of the simplicity and purity of its nature gave rise. It was thrown into vinegar, which so readily attacks copper and iron; it was

brought into company with common sulphuric acid and many other artificial productions which have broken so many strong affinities, but gold disdained to mingle its ancient nobility with this newly-made creation of human art. In vinegar, in sulphuric acid, and in a melting heat, it preserved its purity and simplicity. Even heat which changes so many species of ore into oxydes and dross, served only to purify gold, inasmuch as it volatilised and dissipated whatever was opposed to that purity.

The chemistry of modern time has indeed gone much farther. It has invented quite other and stronger weapons which even the most steadfast metals, the costly diamond and ruby have been unable to resist. It has succeeded in changing gold into the form of vapor, and in dissolving it in acids of vastly greater strength than any which the ancients could command. With its ingenious electrical and electro-magnetic instruments, it has borrowed the power of the lightning, and it has become possible to chemistry to decompose into several substances, water, formerly always ranked among the simple elements, as well as lime, and other earths. But with all these advanced methods it has not been possible to bring the pure simplicity of gold into suspicion. From most of its artificially forced admixtures, it has emancipated itself in the heat of fire, which gives it power to repel foreign matter. It has kept itself as an original substance, as one of those simplest primal forms of polarity, which the power of the Creator called forth in the beginning in terrestrial things.

Substances of the same sort are all the metals proper, of which, exclusive of the metallic bases of the earths and alkalis, there are numbered already thirty. Many of these are found rarely and in very small quantities, and some indeed only as little admixtures in other metals, like the living animals found in the intestines of other living animals, as may be said

of the metals *Rhodium* and *Palladium* when they exist, mingled in small quantities with Platinum.

If great rarity only were regarded, and not rather other valuable qualities, very many of the metals would possess a higher money worth, or as high a value as gold. Such was for a time the case with Platinum. For, in addition to its fitness in composition with iron for Damascus razors and metallic reflectors, &c., this metal, by its extraordinarily difficult fusibility and by its resistance to our strongest acids, proved itself so useful in the preparation of chemical apparatus, that it at once commanded a high price. Even now, when it has been discovered in the Ural mountains in Russia, the price of Platinum, on account of its utility, is four times that of silver; for this dear metal is wrought even into stills for the preparation of sulphuric acid. There are other metals just as rare or even rarer, which are not of so great utility, and among which two, found in and with Platinum, *Iridium* and *Osmium** may be reckoned, whose names, in connection with any purposes of human economy, are as little heard of as those of *Vanadium*, *Cerium*, and *Lanthanum*, or even as those of *Tantalum*, *Titanium* or *Tellurium*, while perhaps *Cadmium*, which is found in some kinds of zinc-ore, is worthy of mention, on account of its use in the preparation of a gold-color for fresco-painting.

Next to gold, which has been appreciated from the earliest antiquity and to platinum, which has recently been discovered, man has ascribed the highest money-value to Silver. Its brightness, its white color, its malleability, and, when it is not alloyed with copper, its property of keeping itself pure from rust, have given it a value in commercial transactions. It comes in much larger masses than gold, and it is reckoned that the quan-

* A composition of Iridium and Osmium has been used for tipping gold pens.

tity of silver, brought from America from the beginning of mining operations there in 1492 to 1803, would suffice to fill a room fifty feet high, fifty feet long and fifty feet broad. In fact, the amount of silver found in America exceeds that obtained during the same time in Europe and Northern Asia more than tenfold, although even Germany has had its fortunate mining periods, when it was able to fill, after a more modest measure indeed, the treasure-vaults of its princes, and, at the same time enrich a large portion of its people. Of pure silver, the mark (sixteen half ounces) stands in value at twenty-four guilders. As, however, a piece of silver money of the same size with a piece of gold, is not more than half as heavy as the gold, so would the latter, if, for example, it was of the size of a silver guilder, be worth twenty-seven guilders. For gold, fourteen and one-third times more valuable than silver, weighs nineteen and a half times heavier than water, silver only ten and a half times.

As to the value of the other metals, useful for human purposes,—it is estimated, not by marks and pounds but by hundred weight. Thus do we reckon the value of mercury, so variously useful, which is between thirty and forty times cheaper than silver, and of copper, which is more than eighty times, and of iron, which is more than a thousand times cheaper. Next to iron and copper, the metals, which have been most used by man from the earliest times are *tin*, *lead*, and *zinc*. For the use made of *antimony*, particularly in medicine, was not known till the middle ages, and till these modern times, to which we owe also the knowledge of the properties as well as of the application of other useful metals, such as *chromium* for painting on glass and porcelain, and *manganese*, used for coloring glass, and also for obtaining oxygen gas with ease, which is procured by merely heating the most ordinary manganese ore (gray brown-stone ore.) In

a melting mass of glass, with which a small quantity of pulverised manganese ore has been mixed, the oxygen destroys the color of the staining parts, and when the manganese ore, mingled with common muriatic acid, is exposed to heat, then, from this acid is formed *Chlorine* gas, which, combined with water, furnishes the bleachers with the means of whitening all cloths and other stuffs which have been colored with animal or vegetable substances, as it destroys those colors. Such a mixture of chlorine gas with water, even gold cannot resist; it is dissolved therein. The calcination or oxyde of the tolerably rare metal *cobalt* is used in the manufacture of a very enduring blue color, (smaltz, silicate of cobalt,) of which one kind is as beautiful as ultra-marine. The yet rarer metal *nikel*, which is found in most meteoric stones, keeps as pure from rust as a precious metal, affords in combination with other ores, valuable compositions (such as argentine, German silver, and others) and is very susceptible of magnetism and can be used in the preparation of a very beautiful, green color. The easily fusible *bismuth* shares, with some of its metallic compositions, with the tin-solder of the tinkers, such a great fusibility that it can be melted at the boiling point of water. The very rare metal *Wolfram* requires, on the contrary a very great heat to melt it. It is distinguished by several remarkable properties, as its gravity, which approaches that of gold. In a red heat, it burns (is oxydised) almost like cinder. *Molybdænum* also is melted with great difficulty and *Uranium* is still less fusible, the yellow and light green oxyde of which is used occasionally as a porcelain color. The above-named ores, however, are of so little importance for practical purposes that they are commonly placed, in the small quantities in which they are found, in the cabinets of the scientific, where they have in their rude state the most value.

Were it the misuse alone, made of any gift of nature, that should make it offensive to us, one might wish in regard to *arsenic* that it were as rarely to be found, and as hard to be got as many of the just mentioned metals. Still arsenic possesses, with its highly poisonous property, several valuable qualities. It causes platinum, so difficult of fusion, to be easily melted and so fits it for alloys. Then again in common with many other metals, with copper, for instance, it forms remarkably beautiful compounds, and its acid, (arsenic acid,) destroys coloring substances, on which account it has become useful in many trades in taking out the colors of many textures. The magnetic power of attraction and repulsion, which belongs peculiarly to iron and nickel, and in a less degree to cobalt and platinum, shows itself analogous to vital force in that, by a slight application of arsenic to the magnetic metal, the magnetic power is as completely destroyed as animal life is by arsenic. Even the fine sound of some metals is destroyed by an addition of arsenic. It is the poisonous property of this metal, however, which man has made use of as a strong weapon against the ravages of the animal world. Wolves and snakes, as well as the destructive bore-worm, must yield to this weapon.

There are still, even among the most useful metals, and the most easily to be obtained, some which, with all their good qualities, may prove hurtful, and even deadly to the well-being of mankind. Such is the case with *copper* with its easily generated verdigris, and with *lead* and its oxydes and combinations with carbonic acid, likewise easily generated. But shall copper, the richest treasure of so many mountain districts, be, on this account, esteemed less valuable, attesting its utility as it does by its ductility, and by being converted into bronze in composition with tin, and into brass with zinc, and by the

the greatest activity and capacity for trade, it gives also the most abundant means for the exercise of their peculiar faculties. An example in point is given us in the busy English, who are wonderfully rich in those metals, which are most serviceable to trade. For England alone produces sixty thousand cwt. of tin, more than twelve times as much as that produced by all the rest of Europe taken together, besides two hundred and fifty thousand cwt. of lead, more than half of the whole European produce; of copper, England produces two hundred thousand cwt.; of iron, a third of the whole amount produced by Europe; of calamine, (carbonate of zinc,) fifty thousand cwt.

The possession of such a treasure of useful metals, which one cannot take in his hand and put into his mouth like other gifts of a prolific soil, but which must be first wrought in various ways, in order to convert labor into money and money into bread, may indeed be adapted to awaken the powers and the activity of a people; much, nevertheless, depends upon the natural gifts and genius of a nation. For in how many countries, where there is want and starvation enough, as for instance, in the Turkish dominions, do the richest treasures of useful materials lie all unused in the earth. But the English, of whose commercial genius, abundant coal mines come in aid, know so well how to put to use the iron which their own island yields, and which is brought to them in part from other countries, that the value of their steel and iron fabrics, may be estimated at one hundred and ninety-two millions of guilders yearly, a sum of which the greater part goes to the capitalists, who advance the needed monies, and are the possessors of the factories, but of which, nevertheless, two hundred and seventy thousand operatives, employed in iron manufactures, have a share.

In England, and in other lands, in which the manufacture of iron is pursued with special success, it might seem as if dealing

is metal had an animating effect upon the industry of a
. And iron, of all the metals, may be said to stand next
For in iron, first of all, is manifested a motion of seek-
nd avoiding, of attracting and repelling, similar and
) the rudimental phenomena of animal life. Iron, as a
t, is capable of being affected by the force of a universal
, like the animal when it yields to the power of instinct.
t, although it combines substances now thus and now so,
by any means able to generate from these substances
ombined elements as are styled organic. Because the
of organised beings, plants and animals, are for the most
rmed of them, we can produce no gelatine, no white of
o butter, and no cheese from the original substances, into
we separate the material world by analysis. Iron, how-
ncroaches in a slight degree upon the more exclusive do-
f vital force, for the sediment obtained from cast iron,
ning carbon, when dissolved in nitric acid by ammonia,
upon being boiled out in water, a mouldy kind of sub-
similar to that which comes at last from the dissolution
ayed plants and animals,—certainly only an approxima-
the process of organic creation from elements, an ap-
nation from the lowest, deepest step. But further, iron is
n yet another way, to stand in a nearer relation than the
metals to the processes of life: it enters as an actual and
influential part into the blood of man and the more per-
imals, and especially gives it its red color.
the substances thus far considered are easily known as
proper, and were known as such to the ancients. For
of them, gold, silver, platinum, quicksilver, copper, and
on, at least in the here and there not inconsiderable masses
ch it falls from the air, are found in a quite pure (metallic)
n nature, as also bismuth, arsenic, antimony, &c. And
hen these just named, and other metals strictly so called,

are found, not pure, but as ores, combined with sulphur or some other metal, or as oxydes, united with the oxygen of the air, yet, according to the laws of ordinary chemical affinity, they may mostly without great difficulty be obtained in their peculiar metallic forms. Besides, all metals, in the strict sense, are distinguished by their specific gravity, which exceeds that of water at least five times. For, excepting Titanium and Tantalum, whose weight is not much over five times that of water, of the better known metals only Arsenic and Chromium are not quite six times the weight of that common measure. Tellurium and Antimony not seven times; Zinc, Tin, Bismuth and Iron, not eight times; White Manganese is more than eight; Ladmium, Molybdœnum, Cobalt, more than eight and a half; Nickel and Copper, almost nine; Uranium, nine; Silver, ten and a half; Rhodium and Palladium, over seventeen; Gold, nineteen and a half; Platinum and Iridium, twenty-one to twenty-three times heavier than water.

16. THE PRODIGAL POOR MAN.

The mention of gold-making in the foregoing chapter reminds me of an account of a man who indeed only wasted gold, he did not make it. But the old gold-makers, had they been distinctly aware of the How and the When of this waste, would not only have made a respectable profit for their pockets, but also have gained some important information in regard to their falsely celebrated art.

On the borders of C— lived a trader, of whom it may justly be said that he gave away in his life time more than many a rich count, more than the good bishop of ——. And further, the man made his presents not in copper or silver, for these he did not readily give away for nothing, but in pure gold. In his daily giving, like a magnanimous benefactor, who does not care

to know what he is doing, he never looked to see in whose hands his gifts were placed, whether friend or foe, Christian or Jew, rich or poor, but he practised his liberality towards natives and foreigners, and especially was every one, who exchanged a crown with him, presented with a gift of gold.

My young readers will justly ask: Was the man then so rich or was he only heedlessly prodigal?

I can affirm with truth that the trader was neither rich nor heedless, and that no one who ever knew him considered him a prodigal. On the contrary, he was accounted in his village and the country round, a man, whose frugality rather exceeded than fell short of the right measure, and who, in matters of trade, where his interest was concerned, was rather over-cautious. The man was no gambler, nor drinker; into his house or even into his mouth there seldom went a glass of the cheapest French wine. For although he possessed a little vineyard, yet such was the quality of the grapes that he deemed it more advisable to sell them to the vinegar-makers, than to make a drink out of them for himself and his family. And so in other things, the economical trader spared as little as possible. He indulged neither himself nor his household in dress or in any expense in eating and drinking, for, as he often said, repeating an old proverb, "Fine bits make beggar's bags." His frugality was hardly to be blamed, for the man had a wife and eight children, and supported also his wife's parents, and from the income of his shop, he could save nothing. Had the chests and boxes of the man, who in his life time had given away thousands of gilders in gold, been examined, the spare-penny, found there, would scarcely have amounted to a few hundreds.

All this sounds very singular, and yet there is something to be added more singular still. It appears as if, in the strange liberalty of this trader, there was something very captivating for others, for all the people to whom he gave gold, gave it

away again to other people, without making any use of it, until at last all these presents passed from hand to hand into the royal mint, which gave the gold to nobody without an equivalent, but yielded a good profit to the government. Let me tell how the matter stood.

In an adjoining country little silver pieces had been coined, of the value of six and three kreuzers, which, when they had been for a long time in circulation, were distinguished by a quite peculiar color. Perhaps the Princes, whose impress these coins bore, wished their likenesses, stamped thereon, to bear witness to their comfortable condition, for, instead of growing pale with age, these faces on the coins assumed a rosy cheeked hue, like the hearty young fellows from the mountains, as blooming, as we say, as a Bavarian Johnny-cake. The art by which this rejuvenescence was accomplished consisted in this, that with the silver of these little coins somewhat more copper than usual was mixed; and as the world then, as now, attached less value to the art and the likenesses than to the quality of the raw material of which the coins were made, the people of the neighboring countries, and afterwards of the country itself, would no longer take the money at the value stamped upon it, and accordingly the six kreuzer pieces fell to four, and the three kreuzer pieces to two. Our trader, living on the borders, had been paid for his tobacco and snuff, for his coffee and sugar, almost entirely in these coins, and he himself bought again what he needed, with the same money. But when the time of its depreciation came, first in one country, and then in several others, the same profit was to be made by the exchanges which took place; and our tradesman, with others, took an active part in this exchange business, satisfying himself often times with a very small profit. The good man did not know what a treasure passed through his hands, neither did the others guess it. Had they been aware of it, they were not in a situation to

possess themselves of the hidden wealth, as the well instructed chemists afterwards did in the mint.

The case stood thus: those rosy cheeked, so called silver coins, were after all not so much to be despised, as people thought. For ordinary use in trade they had not indeed their professed value, and it was necessary that they should be withdrawn from circulation, but the silver, which was taken from them when they were re-coined at the mint, was found to contain, as is often the case with silver, and even copper, a portion of gold, which, in a large number of these coins, yielded no inconsiderable profit. The chemists went to work: they threw these coins broken up (granulated) into strong boiling sulphuric acid, and immediately it dissolved the silver and copper; but it had no effect upon the gold, which fell to the bottom as an unsightly black powder, and could be washed almost entirely pure out of the solution.

But how—what became of the silver? Was it lost? By no means, not a particle. The liquid was poured into leaden troughs, and so large a quantity of old copper added to it that the sulphuric acid was insufficient to dissolve it all. The sulphuric acid, which had united itself with the silver, instantly forsook it, and threw itself wholly on the copper; the silver, in a beautifully pure state, like the so-called native silver, was separated; the sulphuric acid, so far as the quantity used admitted, formed with the copper, blue vitriol, which yields an excellent coloring material, that stands at a pretty high value and price among our tradespeople.

There is much to be learned here, which may be made clear to the understanding by a very simple similitude. Water is standing in our fields, we dig a ditch and the water, by its gravity, flows immediately into the ditch. Near the first, we dig a second ditch, and the water leaves the first and flows into the

second. Thus a dozen ditches may be made, one deeper than the other, and the water will flow down into the deepest, and only return, when the deepest is full, and then it will fill the next deepest and so on.

As the force of gravity affects the water and its motions, in a similar way the force of chemical attraction acts upon different substances. When iron and lead mixed with sulphur are melted together in a crucible, the sulphur immediately combines with the iron and forms sulphuret of iron. So long as a trace of the iron remains in the lead, not a particle of sulphur unites with the latter; only when all the iron is penetrated and taken up by the sulphur, does the sulphur that remains combine with the lead and form sulphuret of lead.

As the sulphur operates in this case, so is it in the above-mentioned process of separating gold and silver by sulphuric acid. As a piece of wood, lying in the ditch, into which an opening has been made for the water to run in, is moved from its position by the water, and because it cannot sink is borne up upon the surface, so the gold is removed from its connection with the copper and silver by the sulphuric acid which falls into combination with the last named substances. It is true this process of separation appears to the eye just the reverse of what takes place in the case of the piece of wood and the water, inasmuch as the wood is lifted from its resting-place at the bottom of the ditch and thrown upon the surface, while the gold in the liquid, falls as a heavy powder to the bottom, instead of swimming on the top. But it is to be considered that in the department of what are called chemical attractions, we have to do with a power, which ultimately indeed acts according to the same universal law as the mechanical action and reaction of gravity, but which nevertheless is of a quite other and different nature and origin, so that the phenomena, which

it calls forth oftentimes cross those which the differences of specific gravity, and which gravitation in general produces, and take a quite opposite direction.

As overflowing water pours itself over fields and meadows, so at first the sulphuric acid, heated to boiling, spreads itself over the metals, susceptible of its influence. It dissolves the copper and the silver. But when the solution is put into leaden troughs, and copper is offered to the acid in abundance for its saturation, then we do, as the farmer does, who digs a deep ditch to carry off the water which overflows his land. The sulphuric acid flows, with a downward pressing force, through all the parts of the copper, and will dissolve the silver only when copper enough is not offered to it, with which it may combine.

We return once more to the consideration of the gold, which, in being separated from the two other metals in the solution, fell to the bottom. As, after being washed out, it presents itself to the eye as a black powder, no one, ignorant of the process that had taken place, would hold it for what it is, for the precious metal, now retaining, of all its obvious qualities, only its gravity. Yet by a further exposure to fire it resumes its brilliancy and color, as well as that cohesion of parts, which fits it for being wrought in so many ways. (chap. 15.)

In our days every well-instructed goldsmith knows that, besides copper, in almost every piece of silver, which our mines produce, some gold is contained. The copper in this raw silver forms three-fifths and sometimes one-half of the whole weight, the gold is indeed mostly only the one-thousandth, or the two-thousandth part of the weight of the silver. Nevertheless, such is the high value of gold, that this small proportion of gold is sufficient to pay the chemists for the trouble of purifying the silver from the copper; we receive back from them just as much silver and copper as we hand to them in

plate or bars, the small quantity of gold which falls to the bottom in the solution, serves to pay them for their trouble.

All this is now, as I have said, a well known matter in our days. But if, a hundred or a hundred and fifty years ago, a chemist, full, as almost all chemists then were, of the chimera of making gold, had, by chemical agency, obtained such a black powder, becoming in his hand, upon further treatment, pure gold, he would have been not a little confirmed in the idea that one metal might be changed into another, that gold might be made out of copper by mixing the copper with a certain poisonous ingredient.

17. THE TRANSMUTATION OF THE LOWER INTO A HIGHER.

Although I have spoken of the impossibility by any means yet known, of changing one metal into another, let me nevertheless relate a case to my young readers in which, instead of iron, copper at once appeared, and if they will go to the place, they may now, by the throw of a fisher's net, instead of an old rusty iron horse shoe, have a beautiful bright copper one.

A miner, so the story goes, in ascending from a mine, dropped an iron scale, of Nuremberg manufacture, provided with a very exact division into inches, lines and tenths of lines. The poor man set a special value upon it, as it had long been in his possession; but though he searched very carefully, it was not to be found. To all appearances it had fallen into the water in the mine. After some time the water was drawn off, and then the scale was found; but, strangely enough, it had become copper; and the same was the case with some of the nails originally iron, which were found upon the drawing off of the water. There was still water enough in the mine, the experiment was repeated, old iron horse shoes, iron cups, and all kinds of articles made of iron, were thrown in, and after a time, instead of

a rusty iron horse shoe, one of copper was drawn out, and the iron cups became copper ones. Who would not now agree with the Alchemists, and believe in the transmutation of one metal into another, of iron into copper?

And yet the case was quite otherwise and quite as simple as the cases mentioned in ch. 16. Water of such a kind, by depositing iron in which, pure metallic copper is obtained, is found in several places, particularly in Hungary near Neusohl. In general these waters are to be found where sulphuret of copper is obtained in abundance. For when the water flows over the scattered ore, or remains standing upon it, the sulphur and the copper combine with the oxygen gas, (of which hereafter,) and there is produced sulphate of copper (blue vitriol) which is dissolved in the water, which thereby receives a sharp taste (of verdigris). When iron is placed in this blue vitriol water, its stronger affinity for sulphuric acid immediately shows itself. The iron is dissolved in the sulphuric acid and water, and disappears from its place, which is filled by the copper in its perfectly pure metallic state. And because the place of every single particle of iron, as it goes into solution, is taken by a particle of copper, the copper in the main, takes the shape which belonged to the metal which it dispossesses, although its surface is often very uneven, and its mass not uniformly thick.

We see here, therefore, not a transmutation of one substance into another, but only an exclusion of one metal by another. A metal, standing at a higher value, has put itself in the place of a more common and lower prized metal, and the lower metal has disappeared. In the spiritual world such ennobling processes, by which a higher and better element of thought takes the place of a lower, are not unusual. In that invisible kingdom there are phenomena which bear witness to a real transmutation (transfiguration) of the low and the base into the high

and the noble, for there reigns there a spirit creating all things new, which works what and where it will.

18. THE METALLIC BASES OF THE ALKALIS AND EARTHS.

The abundance and universality of iron upon our earth and in its depths must arrest our attention. But there are yet other metallic bodies which present themselves, at least upon the surface of the earth, in masses beyond all proportion greater than those of all the metals strictly so called, put together.

Up to the commencement of this century, no student of nature would have thought of regarding the so called earths, such as *Lime*, *Magnesia*, *Barytes*, and *Alumina*, as anything else but elements or simple substances. The same may be said of the caustic *Alkalis*. When our chemists decomposed garnet into clay and silica, and into the oxydes of iron and manganese, when, in Bohemian garnet, in addition to the just named earths and metals, they found also lime and magnesia and chrome, they supposed that they had reached the last and deepest basis of the chemical composition of that stone. Of the possibility of a still further analysis of this substance no one dreamed. In addition to the previously known earths, there had also been discovered in the emerald and beryll, *Glucina*, in the hyacinth, *Zirconia*, in stronite, *Strontia*, and in some other kinds of stones, *Yttria* and *Thorina*, and a new alkali *Lithia* had been distinguished; and all these, just as lime and alumina, were held to be simple elements. In the year 1807, by the discoveries of a great English chemist, Sir Humphrey Davy, a gate was opened through which a deep glance might be cast into the secret nature of substances. These apparent or real substances are throughout nothing but polarizations of matter, through a natural power which is kindred to that of life, and even one with it. As life itself, so also

a use of this natural power is given to man, in a certain measure, especially in electro-magnetical agencies, among which, as we shall see in the sequel, belongs galvanism. The one pole of a voltaic pile, which, on this account, may be designated as the acid pole, every where brings forth the substance of all substances, oxygen gas, from its concealment; the other pole makes apparent the peculiar opposite, (the base), which, just in the particular material body under examination, has associated itself as an external body to the oxygen, that universal centrum of material existences. When, therefore, the usual metallic oxydes are exposed to the influence of the two poles of a voltaic pile, there appears at one pole the metal in its pure, so-called elementary form.

A combination of potassa with water, was exposed by Davy to the action of a very strong voltaic pile, and immediately the supposed simple substance was polarised or decomposed; at one pole of the pile (the negative) appeared a brilliant metal, Potassium. In a similar way a metallic base has been disclosed in the two so-called fire-proof Alkalis; the vegetable and the mineral alkalis, and likewise in lime, magnesia, barytes, strontia and alumina, in a word, in all the above mentioned earths and alkalis; so that now all those supposed elements appear as oxydes, (metallic combinations with oxygen); and indeed tin-stone, magnet iron stone, and red iron stone, or bloodstone, according to their external character, are also oxydes, peculiar only in this, that, in their case, the oxygen gas incorporates itself with its metallic bases in a way, in which the combination could not take place with any of the metals described in ch. 15. For among the metals proper, a considerable difference is to be found in that some of them, as platinum, gold, silver, mercury, iridium, palladium, rhodium, take the oxygen gas, by combination with which they become oxydes, not only with great difficulty, but they give up again this asso-

ciation, when forced to it by human art, and let the oxygen gas go, when they are exposed to only a moderate heat, which, with most of them, does not need to be a red heat, much less a melting one. On the other hand, nickel must be subjected to the heat of a porcelain furnace, in order to set its oxygen at liberty, and, in other cases, some other dainty must be offered to this winged, airy guest, to induce it to forsake its combination with the metal. In many cases, carbon suffices for this purpose. When carbon is brought into contact with the red hot metallic oxydes, the oxygen naturally manifests a greater affinity for the combustible carbon than for the mere oxydisable metal. In the case of the oxydes, however, the oxyde of Tantalum, for instance, it is not enough to bring the red hot metallic oxyde into contact with pulverised coal; a still greater degree of chemical polarisation is required to overcome the affinity of the oxygen for the metal.

But Tantalum and Titanium, approach also the metallic bases of the earths in that they are much lighter than the other metals strictly so called. And in a still higher measure is this the case with the metals of the earths and the alkalis.

A few years ago it would have been an occasion of ridicule had any one ventured to conjecture that there are several metals which are lighter than water, and can float on it like wood. The idea of a metal thus light was so entirely contradictory to the early and established notions which men entertained of metals, that one would have been disposed beforehand to deny a metallic nature to the light bases of the earths and alkalis. But it could not be questioned, when one considered *Calcium* or *Potassium*, or any other body of this kind. The silver or tin-white color, which some of them possess, the metallic brightness which they all have in a greater or less degree, the property which belongs to them of combining (amalgamating) with Quicksilver, or with a metal of their own family and

even with antimony, tin, bismuth and lead, their fusibility, and, in some, their malleability testifies too plainly to their metallic nature.

It may be said that hardly any other department of natural science offers to the natural desire of penetrating to the foundation of things, such nutriment as Chemistry. A youthful curiosity, fresh and earnest, like that of Duval's, must pause over the phenomena presented in the undiscovered world of the earths and alkalis with the same excited interest with which the old Alchemists mixed their compositions in their glass retorts, and watched the substances which they subjected to the fire, the play of their colors, and their motions. What pleasure to follow the threads of analogy which lead from this domain of nature into others. We lay a ball of silver white, shining Potassium upon the surface of a mass of mercury, to which we have previously imparted a slight moisture by breathing on it, and immediately the ball begins a rotatory motion, and describes a path on the quicksilver, the surface of which is immediately purified of the moisture, and becomes covered with another fine casing, which consists of a combination of the potash and water, drawn in the first place from the mercury and then from the air. The ball of Potassium, which, in its motion, has become an oxyde (Potash), and its watery combination (a hydrate,) describes, as the casing sticks to it, a circle growing less and less, and at the moment at which the ball entirely disappears, the quicksilver is covered wholly with a thin layer of Potassa. When a metal ball of the same kind is laid upon water, it instantly begins to move quickly, developing great heat with a reddish flame, on the extinction of which a little clear pearly ball remains, which, however, appears but for an instant and then explodes with a cracking noise. The Potassium has thus, by being burnt with the oxygen gas of the water, been changed into an oxyde (Potassa,) and the heat at

the same time reaches so high a degree that even the hydrogen (of which hereafter) that escapes is inflamed. By similar phenomena is the oxydation of several of the metals accompanied, and we meet here for the first time the agency of those natural powers, which, although varying according to their causes, nevertheless, produce by one and the same law the motions of the celestial bodies round their axes and in their orbits.

There is another metallic body which appears to us still more enigmatical than the nature and properties of the alkalis and alkaline earths, viz: the base of the volatile alkali, ammonia, on this account called *ammonium*. So far as experiment has hitherto gone, we hold that the metals are simple substances or elements incapable of further decomposition. Here, in Ammonium, we find a metal capable of a polarisation, a decomposition into two opposite substances, nitrogen and hydrogen. What new views and changes may await us in regard to the elements and the peculiar condition of their existence and of their persistence, science at its present stage can form no conjecture.

The metallic bases of the alkalis and earths differ also from the metals proper in that they cannot remain pure or even mixed with another, if water or air comes in contact with them, but they must in this case immediately combine with the oxygen gas and become oxydised. Herein they are akin to water, that important element, which everywhere enters, as mediator and participator into the processes of organic life, as well as into the polaric agencies of the unorganised material world. For that basis of water also, which corresponds to the metal of the oxyde, Hydrogen gas, cannot be kept in its purity in the exterior world, but speedily becomes water again in composition with oxygen gas.

Water on the one hand, and the mountainous ranges with which the whole habitable land is connected on the other, constitute the surface of our earth. But that which gives to the

earth its chief solidity, and to the sea its peculiar consis-
, are the oxydes of the metallic earths and alkaline metals,
other words, the earths and alkalis themselves. Alumina
basis of clay) is a chief ingredient of the primitive high
tain ridges; an immense portion of the mountain ranges,
hills as well as of the plains, consists of lime; the mineral
or soda, as a main ingredient of common salt, fills the
as well as the salt lakes and salt beds of certain coun-

Even in the kingdom of organised nature, in vegetable
nimal bodies, lime and the alkalis are found; the former
itself into bones, while of the alkalis, soda, in the form of
non salt, is mingled with the secretions of the body; in-
of soda or the mineral alkali appears in most plants the
able alkali (potash).

an extraordinarily strong attraction for Oxygen shows it-
in the metals of this order, the same attraction is found
e oxydes, arising from their combination with oxygen.
in fact in an increased degree, inasmuch as it no longer
a sufficient supply in the finer, aerial oxygen gas, but
to the denser acids. The oxyde of calcium is the caus-
r so called, *unslacked lime*, the oxydes of kalium and na-
are the caustic alkalis. The burnt or unslacked lime
cts not only the water with such violence that great heat is
rated thereby, but also the carbonic acid, or, with yet greater
rness, the sulphuric, phosphoric and fluoric acids; very
ently it is found united also with silicic acid (ch. 21). The
e of natrium, the caustic mineral alkali, as it occurs in
material world, has found opportunity to combine with a
ance of interesting properties of which we shall speak
ne next chapter, *chlorine*, or what was earlier called
iatic acid. Without the result of this combination, with-
common salt, it would go ill with the economy of indi-
ls and of whole nations.

The oxydes of the alkalis and of the four alkaline earths, Lime, Barytes, Strontia and Magnesia, have before their combination with water and the different acids, a destructive (caustic) effect upon organised bodies, which, especially in the case of the oxyde of Barytes, is so powerful that both in relation to men and animals, it may be ranked among deadly poisons. The oxydes of the other above named earths exist, without any further combination with acids and water, as self subsistent bodies, and show no caustic quality.

Even still, in their concealed and disguised condition, the metals of the alkalis and the alkaline earths act with great force in the relations of the earth and its living beings. Yet more powerful must their agency have been, when they first appeared pure in their decided metallic polarity. What an intense heat must have been generated in the combination of the immense quantities of calcium with oxygen, what motions must have been produced by this process in certain parts as well as in the collective mass of the surface of the planet! There may yet be now in the depths of the solid earth, here and there, single masses of metallic earths, which, by the fixed and firm nature of the matter around them, have been locked up against the water and the air, and which now, when in any way, water is let in to them, produce quakings of the earth, and, where it is possible, many of those fiery outbreaks from the upper rind of the planet, which we call volcanos.

19. A CHAPTER ON CLEANLINESS.

In my travels and during my short residence in Egypt, I often looked with great pity upon the little children of the *Fellahs* or peasants of that country, who live in a condition of great want and wretchedness. These poor little creatures sit quite naked, or wrapt in a few rags before their clay hovels, and

their faces as well as their bodies are so covered with dirt that it is impossible to distinguish the color of their complexions. The dust and dirt adhere so thickly to the lids and corners of their eyes, that they appear to be in danger of losing their sight. Their eyes look so red and inflamed, and must be so painful that the lesser annoyance caused by the multitudes of flies seems not to be regarded, for they seldom make any attempt to drive the insects away. They stare eagerly, half-blinded as they are, at the stranger, with the hope that he may toss them a bit of bread. A benevolent European lady took in charge several of these unfortunate children, had them washed and clothed, taking special care to cleanse their eyes, and when they were fairly freed from their misery and filth, they became so pretty and lively that in a few weeks they could hardly be recognised.

As to water, to cleanse their children and the rags in which they are clad, those Egyptian Fellahs stand in no manner of need. They have the Nile and its canals, or, a part of the year through, quantities of water left in the vicinity of the river after its overflow, in the hollows of the land. But the heavy burthens which oppress the people, the labor to which they are forced, harder even than that under which the Israelites formerly groaned on the same spot, makes them insensible to everything but their animal wants and bodily fatigue; they think only of satisfying their hunger, and take no further care of their bodies.

Even the Bedouins, who guided us through the desert to Sinai and then to Acaba, as well as those who conducted us through the deserts of Arabia, rubbed themselves off, during the journey, chiefly with sand, instead of washing with water; but they had good reason therefor; the water which their camels carried in leathern bottles was hardly sufficient to satisfy their thirst. And when these people, upon whom no hard yoke

pressed as upon the Egyptian Fellahs, but who moved and breathed freely in their deserts, found opportunity to cleanse themselves with water, they gladly availed themselves of it. When one met people of this description, it could be ascertained by their cleanliness, whether they belonged to a free and prosperous tribe, or to a less favored race.

A sagacious and justly celebrated man of science, *J. Liebig*, in his Chemical Letters expresses the opinion that the greater or less use of soap affords a standard whereby to ascertain the condition and culture of States; for the use of this means of purification "depends not on fashion, not on a whim of the palate, but on the feeling of the beautiful, of well-being, and of the comfort springing from cleanliness." A country, in which, with the same number of inhabitants, a greater quantity of soap is used, confirms us in the conclusion, that the condition of its population is externally more prosperous and civilized than that of another, where less soap is used. And not only as to external culture, but also, in reference to the well-being of the inner man, external cleanliness enables us to draw conclusions. A divine of the last century once affirmed that an uncleanly man is no Christian, and that a good Christian cannot endure any dirt upon his outer man. And in fact that the human body is destined to become and to be a temple of God is urged upon us not as an external, arbitrary law—it is written deeply, in the living necessities of our being. There are poor huts in which the greatest cleanliness reigns, because there dwells also in the hearts of their inmates a spirit of purity and order, and there are well built houses, whose interior condition testifies to the reverse.

To the cleansing of our clothes, our chamber-floors, and especially of our bodies, soap affords the most effectual means. It consists in the combination of a caustic alkali with an oily or fatty substance, but the caustic, dissolving, property is so

active that it is capable of readily removing any superficial impurity. Not only to us, but to the nations of the remotest antiquity, the use of soap, as supplying an actual necessity, was known. We find it mentioned in the Old Testament, (Jerem. ii. 22, Malachi iii. 2.) In the time of the Roman naturalist, *Pliny*, it was understood that the ancient Gauls among all the nations of the west were the first acquainted with the preparation and use of soap, (Plin. H. n. xxviii. 12, 2.) And even our German people appear to have been famous, according to the same author, for furnishing the nations of Italy with soap. The descendants, or at least so far as their places of abode are concerned, the successors of both the above-named nations, the French, and among the German branches, the cleanly Netherlanders and the inhabitants of the countries bordering on the North Sea, are still distinguished in the same way. In the universal use of soap they are in advance of all the nations of Europe.

Not only to the higher ranks, but also to the middle classes, among all civilized nations, the use of soap has become indispensable. When formerly the heavy taxes imposed on soap-boilers, rendered it difficult for the poorer sort of people to obtain ordinary soap, the country people in England invented a substitute from the ashes of the fern, the potash of which they mixed with animal fat, and so produced a good article for cleansing.

Our soap-boilers still use the vegetable alkali (potash) for the preparation of soap as it was formerly used by the English peasants. It is obtained by washing out the lye of various plants and then the lye evaporates, until at last a blueish or grayish white sediment remains, which is known under the name of potashes. Out of very many different kinds of plants, trees, and shrubs, from the ashes of our fuel-wood, and also from our vine-wood and straw, this article may be prepared, and in those

countries in which there still exist extensive forests, where superabundant wood must decay unused, great quantities of wood are burnt merely to obtain potashes. In such a way an immense quantity of potashes was formerly and is still produced in North America. From New York alone tens of thousands of barrels have been exported to Europe yearly. The wooded districts of the Russian Empire and of Norway, likewise produce great quantities of potashes, and even in Germany and elsewhere, this article is prepared in no inconsiderable measure from the ashes of the household hearth and from the large fire-places of manufactories. But potashes are not a pure vegetable alkali; they contain of this at the highest only sixty to sixty-three per cent., indeed less than half of their weight, for besides the water and carbonic acid which are combined in them, they contain earthy parts, especially silica and sulphuric acid. Besides, the soap which is prepared directly from the lye of wood ashes (vegetable alkali) is much inferior in solidity and usefulness to that which is obtained from a mineral alkali (soda); on which account, to the mixture of wood ashes, lye and fat, when they are being boiled down to make soap, in order to give it more consistency, common salt is added, the mineral alkali or soda of which unites in part with the fat, while its muriatic acid combines with the vegetable alkali of the lye.

This trouble might be spared, and a much better soap obtained into the bargain, if a solution of soda, instead of the lye of wood-ashes, were used. This strongly caustic alkali exists, as we have said, in immense quantities, for with the muriatic acid there is formed common salt and the sea-salt, which makes the ocean saline. An ounce and more of cooking salt may be obtained by evaporation from water from the ocean, if no large rivers empty themselves into the ocean in the neighborhood; and where the climate permits, the heat of the sun is sufficient

to produce the requisite evaporation in the shallow inlets or artificial hollows into which the sea water flows. And not only the sea, even the land, in some mountainous regions, contains immense masses of common salt, which is obtained just as pure, partly by washing out the clay, and sea-slime combined with it.

But all this abundance of soda in common salt is in itself useful neither to the soap-boilers nor the glass makers, if it is united with chlorine, and must first be separated with much labor from this combination. *Soda*, or the impure mineral alkali, is more readily obtained in easier ways. The same substance, in some countries, especially in Egypt, in the natron lakes of that land, and in Hungary between Debrezin and Grosswardein and in other salt lakes, is found as carbonate of soda, which is tolerably easily cleansed of the sulphate of soda and common salt mixed with it, and is freed by heat from its carbonic acid as well as the carbonate of lime and potash. But even a portion of the vegetable kingdom produces from its ashes the mineral alkali or soda; of this character are some families of the plants that grow on the sea coast or in soils in the interior, abounding in salt, especially the different species of salt sprig, and salt corn or grain plants, and many sea weeds and sea grasses. On the Spanish coast such a quantity of soda is obtained by burning these plants, (Barilla,) and extracting their lye, that many ship loads are exported yearly to Holland. Soda is obtained in equal abundance in Sicily, and especially in the little island of Ustica. In Astrachan and even on the coasts of Norway sea-weed is used for the same purpose.

The mind of man, with its inventive faculties, was not, however, to be satisfied with half ways. What nature accomplishes in the living bodies of plants, namely, the separation of soda in sea salt from its union with chlorine, man's art was

destined to achieve also. As necessity formerly led the country people in England to discover a substance in the roots of the fern, which serves for the preparation of soap, so likewise the trading people in France found out a method of obtaining soda, which indeed was not unknown, but had previously been neglected. France, the country of the greatest soap manufacture, had yearly taken, especially from Spain, twenty to thirty millions of francs' worth of soda, although the price per cwt. did not amount to more than twenty-four or thirty francs. But when, during the war, which Napoleon waged with England, the importation of this article was cut off, many soap and glass makers had to suspend their business, and the price of soap and glass rose immensely. But although the free commerce of the ocean was interrupted, the ocean itself remained to an inventive people. It had long been known that soda can be obtained from common salt by expelling the chlorine of the same by a strong acid. When one hundred pounds of common salt are mixed with about eighty pounds of concentrated sulphuric acid, the chlorine escapes in the form of vapor, and sulphate of soda, or Glauber salts remains. This new combination of soda with sulphuric acid is dissolved by mixing potashes, or still better, chalk with the Glauber salts, and exposing the mixture to heat in a reverberatory furnace until it begins to grow soft, when it is drawn out in iron or stone plates and broken into pieces. Instead of chalk, four-fifths chalk and two-fifths carbon may be added to the Glauber salts. The carbonic acid, which existed in the chalk combined with the lime, or in the other process, was formed by the oxygen, which it drew from the sulphuric acid, unites, in this process, with the soda, while the lime, from which the carbon has likewise withdrawn its oxygen, and which is hereby restored to a metallic state, becomes sulphuret of calcium which is with difficulty dissolved in water. Thus a method was at once found, instead of

obtaining the soda from abroad, of getting it in the country itself, and while, during the interruption of commerce the price of soda had risen to one hundred and sixty francs per kilogram, it sank immediately to eighty francs for pure carbonate of soda, and at a later period even to twenty francs.

The manufacturers of soda found the chlorine gas produced in the preparation of natron or soda very troublesome, and they do so still. Only very recently has its value been discovered. Wherever this gas escapes from the furnaces and chimneys of the above mentioned manufacturers, it spreads desolation in the vegetable world, causing every leaf, every blade of grass to wither. Even to animals and men it is injurious, yet its fatal influence can be more readily averted from man than from plants. The buildings used for the manufacture of soda from common salt and sulphuric acid are erected in uninhabited spots; and in southern France they are placed among the mountain ravines of Septieme, from whose barren soil hardly a blade of grass springs.

Long before the suspension of trade, about 1791, the same chemist, *Le Blanc*, who some years afterwards opened to all the cheap method, above described, of obtaining soda, erected a soda-factory at St. Denis, and was aided with a considerable sum in this useful undertaking by the Duke of Orleans. Many other countries besides France have now taken part in this useful business, and to mention here only those of Germany, there are soda-factories at Schoenbeck near Magdeburg; and even those at Wolfrathshausen near Munich, are not inferior in the amount they yield to the French.

In the preparation of soap, by boiling fat with a solution of lye, the lye under the influence of heat combines with the fatty acids, oleic, stearic, and margaric acids, forming oleates, stearates, and margarates of the alkali. For the polaric opposite of the alkali of the lye is the acid; every substance with

which an alkali or an alkaline earth is to be chemically united, must combine with it in the relation of an acid. In those countries, where the olive-tree flourishes and ripens its fruit, the oil has been used for ages, instead of animal fat, in the preparation of soap. Formerly, before Russia had closed its borders against foreign importation, England drew from that country hundreds of thousands of cwt. of tallow and flax-seed oil. Now her ships bring her hundreds of thousands of cwt. of palm and cocoanut oil, and thus as good and even a finer material for soap is afforded than the Russian tallow.

Some plants produce a soapy substance, which, in its composition and properties is very similar to our artificial soap. Especially in this soapy substance found in the sap of the roots as well as of the other parts of the common soap weed, (*Saponaria officinalis*,) and of a *Begonia*, which is an article of trade under the name of Egyptian soap root, and the slimy soapy sap of which is recommended for the washing of sheep before shearing.

20. AN EYE-MANUFACTORY ON A LARGE SCALE.

The eye is the light of the body, and if the eye is not clear and loses its brightness, then is the whole body dark. A wondrous organ is the eye in its whole structure, and in all its powers. Through the little round opening, (the pupil) which the iris, or *rainbow membrane*, surrounds like a blueish or brownish circle of rays, one can look into the inmost, farthest wall of the eye-chamber. That which glimmers toward us out of this depth, with an almost silver white light, and which, in the eye of the cat, and of many other animals, sheds forth a faint light even at night,—that is a visible coming forth of the inmost life of our material nature, everywhere else concealed from us. It is the marrow of the seeing or optic nerve,

which there spreads itself out with its delicate little tubes, as the texture of the net-work membrane or retina. Nowhere else but at this part of the body, does a nerve, a direct efflux of the mass of the brain and spinal marrow, lie disclosed to our sight. The brain and spinal marrow lie deeply enclosed in their bony vaults, and under the cover of the flesh and skin; and in all the other members, the tender threads of the nerves are concealed by the flesh of the muscles and the manifold textures of the skin. It is here, in the eye, that the inner light of the body meets the outer light of the world, where the outward becomes recognisable to the inward, and the inward to the outward.

When we consider the structure of the eye somewhat more closely, we find that the glimmer of light which is perceptible to us, coming from the retina at the remotest back ground of the eye, and the ray of light, which, coming from without, falls in upon the nervous marrow of the retina, and there produces vision, must pass, not only as in the clear water of a lake, through a single transparent medium, but, as in the case of the achromatic glasses, hereafter to be mentioned, through several. For first there is the transparent, watery-clear horn-membrane, (*cornea*,) whose arched window is ingeniously fitted into the opaque, white, hard membrane of the eye; behind this, between it and the circular iris, which is open in the middle, is a watery fluid which flows out through the open centre (the pupil) of the iris, and also behind this, between it and the crystalline lens, so that the iris, spread out in this fine fluid, can regulate its motions unobstructed, extending or contracting itself, and thus, when the light is too strong, can diminish and close the entrance-gate of the seeing opening, or pupil, and when less light is present, can enlarge it. On the other side of this front chamber of the eye, and its watery fluid in which the iris floats, is the firmer crystalline lens; in

the human eye, and in that of the more perfect animals, this lens is a ball, flattened somewhat towards the back part; in the eye of the fish, when it has become white and hard by being cooked, it is almost entirely round. This too in a perfect eye is transparent, as well as the half-fluid mass, the so-called glass substance (*or vitreous humor*) which fills up the whole back-ground of the eye, and in which the crystalline lens lies embedded, like the kernel of a nut in the cup of the half open shell. A ray of light, when it falls from without in upon the sensitive retina and there produces vision, must, besides the fine membrane, which, like a capsule, surrounds the crystalline lens and the membranous vitreous body, pass through four transparent media of various thickness; the cornea, the watery (or aqueous) humor, the crystalline lens and the vitreous substance.

This is the way in which life everywhere goes to work. It is simply one indwelling soul, which forms and moves the body, and recognises and perceives the external world by means of the body; but this one soul generates and fashions for itself in the substance of its corporeality a great variety of members, every one of which represents on a small scale the relation of the soul to its body, of the Creator to his creation; while the soul, in the realm of being appropriated to it, is everywhere the ground-tone, the key-note, but He, the Creator, is all in all.

What the eye is to the individual body of an animal or man, that the air is and the water, for all living beings; in much simpler ways it is true. When the air is thick and foggy, then a great part of the light of the sun and stars is lost to us. The cloud, which envelopes us at midday when high up on the rocky heights of the Alps, or on the fields of perpetual winter, or on the glaciers, instantly renders it impossible for us to proceed any further on the dangerous way; and the smoke which

sometimes rises at the great eruptions of the Iceland volcanos, and even the coal smoke from the chimneys of that great European capital, London, makes it so dark in valley, and plain and street, that people have to kindle lights at midday. What would become of us, and what would become of most animals and plants, if our planet were not surrounded by this transparent atmosphere, which lets the rays of light and heat down to the lowest plains. What would become of the inhabitants of the ocean, if the sunlight did not descend to them, or shine dimly at least down into the great deep.

It appears, it is true, very dark down in the depths. In the combustion of bodies, (of which we will speak further on,) the air may certainly become a sun on a small scale, a fountain of light and heat, but ordinarily the water and the air resemble only an eye, which must first, by an external light, be prepared and strengthened for vision. Below, in the caverns of the earth, as *Baker* learned, when he, with his family, strayed into the great cave at Levington, no ray of sunlight penetrates, although the stream of air which filled the place was warmed at one end by the daylight. The greater portion of the rock of which the outer rind of our planet is formed, and the earthy soil which covers the mountains, is, to the light, at least to the light perceptible to our eyes, wholly impenetrable. For the few transparent or translucent stones and salts therein, lie for the most part concealed in such dark masses, that no ray of light can reach them. The great Eye of the Earth, the atmosphere, together with the water, possesses the power of receiving and diffusing the sunlight, chiefly for the benefit of living beings, offering the service of that power everywhere where there are beings who are in need of light.

But within the opaque walls of our houses there are living beings who need the light of day, and who find joy in the sun

shine—we and our children. We have built ourselves these houses, that they may protect us from heat, rain, wind and frost. If here and there, besides the door, we make openings for the day light, then with the light, comes the heat or the wind, rain and frost, and like the marmot or the dormouse, when they prepare themselves for their winter rest, we are compelled to close all these openings and remain in darkness. We must think of giving to the dark rooms of our dwellings eyes, which shall receive and diffuse the light within. A body, penetrable to the light, but impenetrable to the air and the wet, and in some degree to the heat, is best fitted to serve our rooms and chambers in the place of eyes.

Animal horn, split into thin leaves, allows the day light to shine through; but the light shining through horn is only a weak twilight, and the horn is so much affected by the light and the weather, that it loses its translucency. Nevertheless, in old times there were horn windows in the huts in which men lived, as well as lanterns of horn. The inhabitants of Siberia have an easier way of providing their dwellings with eyes. In some mountains of that region there are large masses of a kind of stone, called Mica, which is easily split into plates and thin leaves, and which, especially when it is of a light color, is translucent in a pretty high degree. But out of Siberia, there are very few places in which mica can be found of a sufficient size to admit of plates being cut from it several inches square; if we had no other substances to give light to our dwellings, ninety-nine houses out of a hundred would have to remain without eyes. The evil would be yet greater, if, instead of mica and horn, we had to depend upon the translucent shell of the *windowpane muscle*, (*Placuna placenta*,) which is found particularly in the Chinese sea. This material is so rare that scarcely the thousandth, or rather the hundred thousandth part of human dwellings could be furnished with eyes.

The Phenicians, it is said, first succeeded in discovering a way of meeting this urgent and universal want. The invention was so nearly made by the Egyptians, that they may have known and, although only partially, practised, the art of making glass, even before the Phenicians. For the specimens of glass, found with their mummies, which have been buried three, and perhaps four thousand years, show that the Egyptians were originally masters of that art. It required only the fine sand of the valley of the Nile together with the mineral alkali or soda, which exists in their lakes, and which, in many places on the northern coasts of Africa, as at Tripoli, can be scraped from the rocks (the Trona-Soda,) to be subjected to a strong heat, and a combination is formed in which the silica takes in opposition to the alkali the place of the acid; this combination was and is Glass. And not merely soda, but vegetable alkalis also, such as potash, and even common wood ashes mixed with silica, and subjected to vitrification in fire, give a more or less transparent glass. For in the mass, from which our dark colored bottles are here and there made, there is no pure alkali, but it consists chiefly (apart from the common salt or lime mixed sometimes with the fluid at pleasure) of one hundred and sixty parts of wood ashes, one hundred parts of quarz-sand, and fifty parts of basalt. When in these combinations of silica and the alkali, the latter predominates, when, for instance, five parts of the caustic alkali are united with one part of silica, there arises the silicious fluid, which is easily mixed with water, (soluble glass.) In the preparation of pure glass, when pure alkali is used, six parts of silica and one part of the alkali are employed. To the fusion which gives us the so-called mirror-glass, is generally added saltpetre, and a small quantity of manganese ore, and in the manufacture of flint glass, even a slight addition of white arsenic and a large portion of red oxyde

of lead, in order to render the mass colorless and clear, are found advantageous.

Before all other substances, besides the silica, which is every where found in great abundance, it is Potashes, and especially soda, which renders it possible for human art to introduce light into the darkness of our dwellings, and which is to be used for the universal and daily want of windowpanes. This application of the old invention, the Romans understood and practised, as has been discovered through the single windowpanes found in the houses of the city of Pompeii, which, in the year A. D. 79, was buried at an eruption of Vesuvius under a shower of ashes. Glass, formed into square plates, the lighter the better, allows the light to pass through it, but presents a screen against the heat, of a stove for instance, in like manner with opaque bodies that are not metallic. On this account glass possesses all those qualities which a medium ought to have, which is calculated to guard against the weather and to communicate light.

In its use for windows, whereby the largest portion of human dwellings were rendered truly habitable, the invention of glass brought a great advantage to the nations of the earth. This use of it was in its consequences vastly more important, than the other uses made of the art, such as the making of colored glass in imitation of precious stones, or the manufacture of various kinds of vessels which are recommended by the ease with which they can be kept clean, as well as their transparency and form. Yet another use of the art of glass-making was reserved to a later age, which not only gave to our dwellings their light, but to man himself new and higher powers of vision.

The first step in this domain of invention was that by which men learned by artificial means to restore to old age the power of youthful vision.

negro king to be almost a hundred fold greater than it actually was. Nevertheless, this prince, so opulent in gold-dust and ivory, hesitated not a moment to pay the price. Perhaps he expected that with the artificial restoration of the noblest organ, the vigor of youth might be restored also to his whole body. Of all the ship's company, the sailor boy had made the most profitable business, when he returned, according to his rank quite a rich man, to the house of his father, the old spectacles-grinder.

More intelligible still than the joy of the old negro prince at such a renovation of his eyesight was the rapture of the old brahmin when the excellent spectacles, which an Englishman had presented to him, at once enabled him to read the sacred books of his Law, which he had not been able to do for many years. It is precisely in this business of reading that the old perceive most painfully the loss of sight for near objects, their power of seeing at a distance remaining the same, and when the aged man, who is unable to distinguish any writing with his naked eye, puts on his spectacles, he can read at once. However, one must not carry his expectations of the spectacles-maker's art quite so far as that peasant who went to a Fair to purchase what was needed at home. He stood at the stall of a dealer in spectacles, and saw how several people made their purchases. A book, with fine print was handed to them, they put on one pair or another of spectacles and then looked attentively on the book. "Can you read well with those?" the dealer asked, and when they answered in the affirmative, the bargain was soon struck. The peasant then conceived a desire to purchase a pair. He approached the counter, took the book, put on a pair of spectacles and looked into the book, but put off one pair after another with a shake of his head. The trader, wishing to assist him in his choice, offered him various pairs, which he thought would suit: the remark of the

peasant remained always the same: "I cannot read with them." At last a person, who had come to buy, said to the peasant, "Friend! tell me pray, do you know how to read?" "You fool!" replied the peasant, "if I could read, I would not be buying spectacles."

Familiar as we are with spectacles, they were not invented immediately upon the invention of transparent glass. A writer of old Rome, Seneca, has indeed remarked that through a glass-ball, filled with water the letters of a book were seen in a magnified form; and an Arabian writer of the eleventh century, named *Alhazen*, states, that by means of a glass ball, all kinds of small objects may be seen enlarged. There was a long interval, however, between the knowledge of this fact, and the representation of such flattened, round (convex) ground glasses, as render the same service in a much better and more convenient way. The use of such glasses, raised on both sides, for eye-glasses or spectacles, was taught to modern nations by the Italians. The first inventor of spectacles was a nobleman of Tuscany, named in the inscription on his grave-stone in the Church of Maria Maggiore at Florence: *Salvino degli Armati*. He died in 1317. According to others, to the Dominican monk, *Alexander de Spina*, who died in 1313, belongs a part of the glory of the invention, or at least of its more common application. For when Spina had seen and admired a pair of spectacles and had in vain inquired of the man, in whose possession they were, how they were made, he betook himself to work, and without further delay, fell upon the plan of giving a convex surface to a round disk of glass by placing it in a saucer-like concave cup, and by rubbing or grinding it down for a long time with a fine powder of rotten stone or emery. Two glasses of this description, were at first placed in a frame, at a distance from each other corresponding to the distance between the eyes, and fastened to a cap which

was drawn over the brows when the spectacles were to be used, and afterwards pushed back. Soon the bows or arms of the spectacles were added, made of horn, and the spectacles were bent in front so as to rest upon the nose. It will here be in place to speak of the contrivance and effect of magnifying glasses and of the reason of their effect in general.

Besides the property of magnifying objects, we all know that (bean or) lens-shaped glasses have another property, by virtue of which they serve as burning-glasses to set on fire combustible bodies: the property of directing all the rays of the sun, which fall upon the different parts of the glass lens, to one point, the burning point, (or focus.) The greater the surface of a burning-glass, and the nearer, by virtue of the convexity of its surface, the focus lies to the glass, so much the greater is its power. This can yet be seen in the large burning-glasses which *Tschirnhausen*, a German nobleman of Upper Lusatia, caused to be made by means of a mill made for the purpose. Two of these gigantic glasses, made about the year 1686, and weighing more than a hundred weight, are yet in Paris, their diameter is thirty-three inches; the focal distance of one is seven feet, of the other twelve feet. Wood thoroughly wet is set on fire, and even pine-wood lying in water is instantly charred, metals melt, water boils, when placed in the focus of such a glass. Tschirnhausen was at a great expense in the preparation of these burning-glasses, which however render no particular service to science; he would have done vastly more good by glasses of a cheaper kind. When for instance two concave glasses (somewhat similar to large watch-crystals) are joined together at their rims and the space between them is filled with turpentine, we have an instrument, in whose focus the effect of the sun's rays here concentrated is immensely increased above that of a glass lens. Two French men of science, *Brisson* and *Lavoisier*, prepared such a burning-glass in the

year 1774, filled with turpentine oil, which was four feet in diameter and eight inches thick in the middle. Connected with a common glass lens, which was placed between this great instrument and its focus, and which collected the sun's rays that passed through the same to a nearer and smaller focus, this contrivance had such uncommon power that the hardest metals could be fused. Copper coins, which in the focus of Tschirnhausen's lens took three minutes to become fluid, melted here in half a minute, iron laid on a coal almost instantly. We see something of the same kind on a small scale when the sun shines through a round bottle filled with water, and the focus falls on a combustible body; conflagrations have been occasioned in this way.

The ancient Greeks, who were very well acquainted with the property of setting inflammable substances on fire, possessed by crystal balls, such as are found in many rivers (as the so-called Rhineflints in the Rhine,) wondered at the relation between the crystal and the fire which it occasioned; the crystal remaining cold, while it set other bodies out of itself in a flame. The reason of this lies tolerably near at hand, and becomes evident when we consider a so-called concave mirror. If the form of a shallow broad basin is given for instance to a mirror of metal or glass, and the same is placed with its centre in a straight line with the sun, all the rays of the sun are reflected back in a direction, the reverse of that which water poured into a tunnel takes, towards a common point which lies in a straight line with the centre of the mirror. Every single point of the burning mirror is thus heated no more by the ray which strikes it than any other piece of metal or looking-glass, but the power of the light, reflected by them all to a common point, is so great that the hardest metals may be fused, and the diamond evaporated.

In the case of the transparent glass, however, to which the forms of magnifying and burning glasses are given, there comes, before all things, to the aid of human art, an essential universal property of transparent bodies, the *refracting power* of the same.

Every child may remark that when a stick is partly inserted into the clear water of a lake or river in a slanting direction, and when it is looked at side-ways, it appears as if it were broken at the surface of the water, as if it consisted of two sticks, one of which extends straight to the water, and the other, somewhat sideways from the former, begins at the surface of the water, and takes a direction not in a straight line with the part above the water. When one lays any heavy, shining body in the bottom of a vessel, and takes a position at such a distance from the vessel that the body, deposited in it, is hidden by the rim of the vessel and cannot be seen, then if the vessel is filled with water, the shining body will again become visible, as if it had moved from the place where it lay towards the side of the vessel farthest from the eye, and yet this is only apparent, it remains unmoved in its place. An illusion similar to this was experienced by the Dutch voyager, *Berenz*, and his companions in suffering, when, surviving the fearful hardships of a long polar winter night, they saw morning dawn again. The sun appeared over the ice and snow fields of the horizon nineteen days earlier than it was expected by exact calculation; but this visibility of the sun's disk, which was still actually below the horizon, was occasioned by the refracting power of the thicker strata of the atmosphere.

When one takes a stick, as mentioned above, and places it standing upright in the water, and then looks down in a straight line from the upper end to the lower, no breaking of the line is apparent. The stick continues to our eye under the water in

the same direction, which it has above in the air. When now a ray of light, proceeding from a luminous or illuminated body, passes in an oblique direction under a greater or less angle from one transparent medium into another, it will to our eyes appear, if the second medium is denser than the first, to be broken in a direction which lies towards the line perpendicular to the surface of the second medium at the point where the ray passes; as it is with the example which we have mentioned, where a shining body, lying at the side of a vessel, after water is poured in, is at once seen nearer to the centre of the vessel. The reverse takes place, when we employ a vessel, the upper half of which is filled with water, while the lower part, separated from the upper by a transparent partition, contains air. A shining body, lying in the lower part, will appear to us, when we stand at a proper distance from the imaginary perpendicular line drawn from above downwards through the centre of the vessel, to be at a greater distance from that line, and moved toward the side of the vessel nearest to us.

When the ray of a body illuminated by the sun, falls from the vacuum in an air-pump into the common air of our room, it suffers a refraction of the last mentioned kind; on the contary, if it passes from water into a solid transparent body, it suffers the opposite refraction. The density of bodies is not the only circumstance which causes the higher or lower degree of the refracting power of the light; the quality of the transparent substance exerts an essential influence. Combustible bodies, which on being ignited become a source of light, exercise upon the light, which passes through them, the strongest influence. When the great *Isaac Newton* inferred, from the strong refraction of the light in the transparent diamond, that this stone of stones, this hardest body of the earth, is of a combustible nature like oil and wax, and published his conjecture of the combustibility of the diamond in his

Optics, many of his scientific cotemporaries may have laughed at the idea; and yet, his supposition was shortly afterwards confirmed, when Kosmus III., at Florence, in the year, 1694, consumed for the first time a diamond in the focus of one of Tschirnhausen's large burning glasses. As among all solid bodies, the diamond, phosphorus, sulphur, and the combinations of carbonic acid, and of sulphur with some of the metals when they attain to transparency, manifest the strongest refracting power, so, among the fluids, the easily inflammable essential oils, and spirits of wine, and among the gaseous bodies, hydrogen gas or inflammable air, possess the same property.

The same thing, which occurs, in the appearance of a stick when held in an oblique direction in water, takes place in the case of every ray of light, which passes from the air into a denser transparent body, whose surface is, not flat, but as in a glass ball or lens of glass, bent and rounded. The rays of light fall towards the thinner rim of such a lens, more and more obliquely upon the surface, and, according to the law which regulates the passage of light from a rarer, transparent medium into a denser, become broken or bent, towards the line passing through the centre or axis of the lens. When we look through such a lens, not merely do the unchanged, straight rays, which an illuminated body sends through the middle of the lens, fall on the eye, but those rays also which strike upon the curved parts of the surface; and the body appears to us magnified in a high ratio.

In the way thus generally indicated, do those artificial eyes operate, which man has obtained the use of since the employment of glass in the preparation of spectacles and burning glasses. We propose here to mention a few facts tending to show how the sphere of our knowledge has been enlarged by these great inventions.

The power of convex burning glasses to collect the rays of light and magnify objects was long known and used for objects near at hand. A magnified body appears to the eye to be immediately brought near. When the means had been found of applying magnifying lenses to the examination of remote objects in such a way that the rays of light passing from an object into the lenses and refracted by them, could be collected in the eye, undisturbed by the stronger light, reflected from near objects, then to the human eye as to the human mind was given the power of converting remote space as well as the remote past into a near present. The glory of the precise invention of the telescope at the beginning of the 17th century, may fairly be given to Hans *Lippersheim*, a spectacles-maker at Middleburg, a native of Wesel, not, as was formerly supposed, to *Zacharias Jansen*. The former, it is said, was led to the discovery by his children, who, when at play, put some of their father's prepared spectacles-glasses into a paper tube, and so saw the weather-cock of the tower greatly magnified. As more remote objects reflect a weaker light than those that are nearer, the impression, which they make on the eye, is destroyed by the light of near objects, just as the light of the stars is eclipsed by the rising sun. Hence, when we wish to see distant objects more distinctly, we are accustomed to look at them through the hand; and the ancients, long before the invention of the art of glass-grinding, observed the stars through long tubes, by looking through which, the light coming from other quarters is shut off from the eye, which is thereby better fitted for the undisturbed reception of the light coming from the object under observation. So from a mine or well a star may be seen at midday, when it stands directly over the well; the sides of such a deep hole keep off the rays of the sun, and of other objects illuminated by the sun, so completely from the eye, that the star can be distinguished at

noon as distinctly as it may be seen in the morning twilight before the rising sun has touched the mountain tops.

In a simple tube, which rendered it easy to fix the glass firmly in the right direction, a convex ground glass was placed, and then another glass was placed in the focus of the first glass, which threw the image received and magnified by the first upon the eye, still further magnified; and thus the means was obtained of seeing distant objects as large as if they had been brought twenty or thirty times nearer to the eye. As the convex lenses represent the image of the object in an inverted position, there was at first added to the object-glass (i. e. the glass which at the farthest end of the tube receives the rays of light from without,) a concave ground eye-glass at that end of the tube at which the eye is placed. This eye-glass has the opposite effect of convex lenses in representing objects; it gives back its right position to the image which is presented by the object-glass inverted. Instead of the concave lens, however, there were employed afterwards, in telescopes for terrestrial objects, several, perhaps three or four eye-glasses, by the alternate effect of which the object becomes upright to the eye. For the observation of the stars there was, besides, given to the eye-glass the strongly magnifying flat-ball form.

The application of magnifying glasses to the examination of remote objects lay so near to the inventive faculty of man, that any ingenious man who had once seen a telescope, or only heard of its construction could make one for himself. Hence with Lippersheim almost immediately came his fellow-citizen and associate in art, Jansen, with telescopes made by him; and it was vain that Prince *Moritz* of Nassau, who discerned the importance of the invention in war, endeavored, as is said, to keep the invention secret. In the year 1608, a telescope made in Holland, at Frankfort on the Maine, was offered for sale at a monstrous price at the Fair. A distinguished man from Ans-

bach, the privy counsellor *Fuchs* of Bimbach, saw the same, and upon his return home described its construction to the celebrated astronomer, Simon Marius (Maier.) Common spectacle glasses were too convex, but the glasses of a flat round form which Marius had ground according to his directions at Nuremberg, did not answer the due purpose, which was attained only by glasses from Venice, wherewith Marius constructed that telescope that enabled him, in November, 1609, to see the four satellites of Jupiter. But in the same year the celebrated *Galileo* made a telescope, according to a description he had heard at Venice, and carried it afterwards to such perfection that some of the instruments of this sort, prepared by him, possessed the power of magnifying an object more than sixty fold. The English also, in the year 1610, were in possession of telescopes, made probably by themselves, by which they could distinguish Jupiter's satellites, for which, however, no very powerful instrument is requisite. A year afterwards (1611) the great German mathematician and astronomer, *J. Keppler*, in a work upon this subject, gave the first strictly scientific account of the construction of a genuine astronomical telescope.

The desire to investigate the unknown miracles of the visible world received from this time a powerful stimulus. What a delight must it have been to the eager Marius, to discover that, as the earth had one moon, Jupiter had four! With what astonishment and rapture must Galileo have been filled, when he looked at Saturn through his telescope and saw on the sides of its disk two bodies, which he at first took to be two great moons, never moving from their places, but which he afterwards found to be parts of a remarkable ring, which, alone of its kind, surrounds this planet, and revolves with a swift motion. This celebrated man immediately discovered also through

his telescope, that the planets, Mercury and Venus, because they stand, at a part of their orbits, in a line with us and the sun, or on one side of this line, sometimes appear, just like the moon, full, sickle-shaped, or half-full, with a waxing or waning light, accordingly as they turn to us, with a portion of their disks illuminated, the unilluminated part also. Quite new and unexpected discoveries were made also in regard to the sun, when, in the years 1610 and 1611, almost at the same time, *Christopher Scheiner* in Ingolstadt, *John Fabricius* in East Friesland, and *Thomas Harriot* in England, discovered and observed in the pure fountain-light of our planetary world, dark spots, which, as we shall see hereafter, are phenomena, generated in the atmosphere of the gigantic body of the sun; not stationary on the sun's disk, but moving over it from west to east. A sun-spot which first becomes visible to-day moves onward until, in about 14 days, it reaches the eastern rim of the sun, when it disappears; and again, after the lapse of the same period of time, is seen on the western; whence the above named, first discoverer of spots on the sun, drew the correct conclusion, that the sun moves round its axis, like our earth, from west to east, but, not in 24 hours, but in a period of nearly four weeks. With what a far nobler and more elevated sympathy did civilized Europe receive intelligence of the conquests made by science in the starry heavens, than, at a later period, it read the newspaper accounts of victories obtained by some warlike king in the domains of his neighbors!

And yet the grand discoveries of that age were only the first step towards the enlargement of our knowledge of the heavens. With what delight would a Duval have heard what astronomy now tells us about the stars,—the intelligence, that there, in the upper, remoter regions of the universe, suns are moving round suns, like our moon round the earth; that, not only the pale

light of our milky way consists of the beams from many millions of distant stars, but that, at immeasurable distances, beyond the region of the milky way, there are yet other hosts of stars, millions strong, whose united light falls, from that great distance upon the eye, only as a dim nebula of light. For the distance from us even of the nearest fixed stars is so great that a ray of light, which passes over a space of about 192,000 miles in a second, can reach us, from those stars, only in 3, 9 and 12 years; indeed, from those remotest realms of space, whose shining worlds are visible to us only by a scarcely distinguishable glimmering of light, a ray would arrive at our eyes only after the lapse of thousands of years.

And not less worthy of attention than the spectacle of the heavens, unveiled to us in those distant quarters, is the knowledge which the telescope gives us in regard to the nearer heavenly bodies. Upon our neighbor, the planet Mars, the telescope shows us the white masses of snow, which, in winter, cover its polar regions. When, at a certain part of its annual course, its northern hemisphere is turned towards the sun, and when it thus becomes spring and summer there, then the great white spots upon it are seen gradually to diminish, for the snow is thawed by the sun's heat. But at the same time winter takes place on the southern hemisphere of the planet, and there the white zone of snow grows larger and spreads itself out; and so again when the southern hemisphere has its summer, the northern is visited by winter. So that we can almost tell, when our neighbor Mars has, upon its northern hemisphere corresponding to that part of our earth where lie Europe, Asia, and a part of America, a long or a mild winter. But besides the snow-masses a good telescope shows upon the planet Mars the dark colored portions of water and the lighter colored regions of the land; and some observers have even believed that they discerned the clouds in the atmosphere of

that planet, so that we may suppose that Mars is very similar to our earth.

On Jupiter and Saturn also the telescope has made singular discoveries, which, however, do not harmonise, like those made in regard to Mars, with the arrangements of things on our earth. For around the surfaces of these great planets pass great belts, apparently of clouds, which do not, like our clouds, come to day and disappear to-morrow, but, as it is by no means comfortable to think, remain stationary with little change for more than a hundred years, so that if people, like us, dwell there, many an aged man, if he has always remained in the same place, sees the sun hardly once in his whole life. On the other hand, the inhabitants of Venus and Mercury have little reason to complain of too much rain, as there the skies appear to be almost always serene.

As the telescope has led to the discovery, by means of the spots on the sun, that the noble king of day does not stand fixed and immoveable, but revolves round his axis once in nearly four weeks, so has a similar discovery been made, by the same instrument, in regard to the other bodies of the solar system. Mercury, Venus, and Mars revolve on their axes in about the same time with the earth. From noon to noon, their inhabitants, if they are inhabited, have not to wait much more or less than 24 hours. The space between midday and midday on the planet Jupiter is only 9 hours and 56 minutes, on Saturn only 10 hours and 16 minutes. It would seem as if this swift alternation of day and night were intended to compensate for the slow alternation of the seasons, for on Jupiter winter lasts almost 9 of our years, on Saturn almost 15; while the lively little population of Mercury have to wait, at the beginning of winter for the beginning of spring, only 3 weeks (22 days,) although indeed the spring there passes as quickly into summer, and the summer into autumn.

Our nearest neighbor, the Moon, has indeed its year of the same length with ours, for it accomplishes the journey round the sun in company with the earth, but at the same time it has a day 28 times longer than ours, so that there for 14 of our days the sun stands in the moon's sky, but then again the darkness of night lasts there through an equal period. In regard to the nature and condition of this nearest world, whither a good walker, were there a road to the moon, might arrive, supposing he travelled every day 10 leagues, in 28 years, (he would not reach the sun at the same rate in 11,000 years)—the greatest discoveries may be expected by means of the telescope. Yet these expectations must not be carried too high. The Moon is 238,000 miles distant from us; if now one of our telescopes possess the power of magnifying four or five thousandfold, we should gain simply this, that the moon might be examined as distinctly as if it were some 50 miles distant. No æronaut in the moon could ever get so near the earth as to look into our windows, but in a perfectly clear atmosphere our seas, lakes, and mountain ranges might be distinguished. On this account, many remarkable facts, as we shall state hereafter, are known concerning the Moon.

By the new eyes, which man has obtained by melting together an alkali and silica, the sphere of his vision, as we have just seen, has been extended a thousand fold into the distant; and in the same proportion has his power of vision been sharpened for things near him. As the glass-grinder knows how to make spectacles for the eyes of such old people as see well at a distance, but poorly what is near, and at the same time, other spectacles, made for those whose defect of sight is precisely the reverse, so has Art turned the telescope (or distance tube) into the microscope, which for the world lying close to us, possesses so penetrating a power that one can distinctly discern, through this instrument, objects several thousand times finer

than a hair, many hundred times smaller than an atom of dust.

When the eyes of the short-sighted are closely examined and compared with those of the far-sighted, it is readily perceived that the former are more rounded and prominent, while the latter are much flatter. When eyes of both kinds, the high and round, and the flattened, are otherwise sound and strong, the former serve best to see what is near, the latter, what is distant. As the human eye, by increasing age, when all the vital fluids of the body lose their exuberant fulness, grows flatter, becomes less round, it frequently happens that people, who were very short-sighted in their youth, become far-sighted with increasing years, without having their sight for near objects seriously impaired. On the contrary, very far-sighted eyes must in old age be assisted by spectacles, when a near object is to be closely looked at, and indeed by spectacles with glasses ground convex, while the glasses with which the short-sighted examine distant objects must be somewhat concave.

The inventors of the telescope have, in the shape of their glasses, imitated the form of the far-sighted human eye, and the inventors of the microscope, the form of the near-sighted. Those microscopes, which were made just after the telescope became known, by Zacharias *Jansen* and his son, were not by far so powerful in magnifying very small, near objects, as those constructed later (somewhere about 1660,) by *Hook*, because the latter used glasses almost round, while flattened convex lenses were previously made use of.

Thus were obtained also artificial eyes, by which the advantages, possessed by the sound short-sighted eye, through its acute vision for near objects, were increased a thousand fold, just as the peculiar sharp sight of the far-sighted was aided by the telescope. By the invention of the microscope, a depth in the Divine Creations, the before unknown little and minute, has

been opened to the appetite of knowledge, a depth, as immeasurable and full of miracles as the great world which has been disclosed by the telescope. In every drop of water, in every animal or vegetable substance, when decomposed or dissolved, there is presented to us through the microscope an animal world, which, in variety of form and kind, is as manifold as that of the great land and water-animals that we see with the naked eye. Everywhere, where there is a nourishing fluid, growth is going on, life stirring; even on the snow dwell, here and there, millions of microscopic animals, a space as large as the square of a line may contain many thousands of the same; a distance as great as the breadth of a hair is for many of these animalcula as much as a quarter of a league for us; through the finest, most delicate vessels of the human body, which are too small for the finest hair, these minute creatures could pass, as easily as we, through the doors and gates of our cities.

But not only in the wide spaces of the external world, even in the inner world of our own bodies, and of the bodies of animals and plants, the microscope has revealed things, of which the learned of former times had no guess. Thus the form and quality of the little, lens-shaped particles of the blood, and the fine tubes of the nerves are found filled with a fluid, in which the powers of life work all their miracles. Through the microscope may be seen the motion of the nourishing fluids in the transparent wing of a fly, the structure of the intestines of a cheese-mite, the course of the nerves and the arrangement of the muscles in the foot of a spider, the gradual formation of the young in the egg of a flea.

All this has resulted from the invention of Glass and its ever extending uses; but we could not have glass from silica, had we not the alkalis; had we not potash and soda-ash, or the soda obtained from it. Thus even the process in the development of our knowledge depends on threads, the end of which

is connected with an incident, which perhaps occurred at a shepherd's hearth, in the fire of which a lump of natron, from an Egyptian lake, was melted with sand into a transparent mass.

21. THE BASES OF THE ACIDS.

The elements, which we are now to consider, have been in part comprehended under the name of combustible bodies. *Selenium*, which is ranked under this head, has several qualities in common with the metals proper, especially a metallic brightness, and a gravity, which exceeds that of water four times. Through other properties it approaches, nearer even than arsenic, to sulphur. As a substitute for this it exists in Tellurium ore, combined with the metal, (Tellurium,) and with iron in pyrites (sulphuret of iron,) as also, here and there, in company with volcanic sulphur. Like all those existences in nature, which are neither entirely one thing nor another, Selenium plays among material substances, a very ambiguous part. Its combination with hydrogen gas appears to belong among the strongest poisons; and we need not by any means regret that selenium is so rarely found.

Vastly more decisively than the just mentioned substance, has *Sulphur* taken to itself the nature of a combustible body. On account of the abundance in which it exists, it maintains also a vastly higher rank among the constituent forces of the earth. It is found in a pure state and in whole masses, especially in Italy and Sicily, and also in Spain and Poland. At Scansano, in Tuscany, the mass of sulphur, dug up in eight months, amounted to four millions of pounds. Sicily exported only a little while since, between 20 to 30,000 cwt. yearly. At the craters of volcanoes, especially in South America and Java, it is found in a pure state; it is also frequently obtained from

sulphuret of iron. Sulphur in its combinations with the metals takes the place of oxygen, and when a sufficient quantity of this suffices to produce an oxyde, a double weight of sulphur is required to supply the place of the oxyde in the ore. In the combination of sulphur with metals, an emission of light is in many cases perceptible, as in the combustion of bodies with oxygen gas.

But sulphur also enters readily in combination with oxygen gas. It ignites in contact with fire, and becomes then sulphurous acid, the offensive suffocating smell of which is known to us all. When oxygen gas, in yet great quantities, unites with sulphur, there is produced sulphuric acid of a higher degree, which, in a state combined with water, is called *oil of vitriol.* Sulphuric acid has been formed in great quantities in the construction of the earth; and with lime becomes gypsum; it is met with, here and there, dissolved in water, in the vicinity of volcanic craters. Sulphur is often found among the component parts of plants, and constantly, even in the human body, where it betrays its presence in the interior as well as in the exterior parts—in the brain, and even in the hair.

Phosphorus, however, enters still more essentially than sulphur into the composition of the human body and of the more perfect animals. In the mass of the brain and the nerves, it is united, as in the form of an acid, with lime. It is found in the bones, and even in the urine. *Kunkel*, a chemist, who followed the art of gold-making, discovered this remarkable, easily inflammable body, which, itself, without actually inflaming them, communicates to bodies rubbed with it, the property of shining by night. Man has had it with him and carried it about with him in the inmost parts of his body, ever since his race existed, from birth to the grave, without ever having been conscious of this possession. So much is there that is in us, and goes with us, of which we know nothing.

In external nature, the easily inflammable phosphorus is not found in a pure state, but only in its union with oxygen gas, as phosphoric acid, and even as such, not pure, but united with metals, as, for example, lead, iron, and with lime. Although it exists among the component parts of the human body, yet it can act upon the body as a strong poison. A very small quantity of phosphorus, introduced into the stomach, is fatal.

Phosphoric acid, in many of its properties, resembles *Fluoric acid*, which, combined with lime, forms the for the most part vari-colored *Fluor* spar, Derbyshire spar, and with alumina and silica, the *Topaz*. The nature of its base is still very little known; one of its remarkable properties is that it readily attacks and dissolves silica, so that one may etch with it in glass. Upon most of the metals it acts as a solvent. It must be kept therefore, in order to preserve it pure, in bottles of platinum or gold. Hydro-fluoric acid, of a high degree of strength and purity, belongs among those bodies, which occasion great danger and pain to those who discover and examine them. When a finger is touched with the point of a needle, which has been dipped in this acid, a sleepless night and a light attack of fever are the consequences. When a finger is only exposed to the fumes of hydro-fluoric acid, festering and malignant sores form, after violent pain, which are healed only slowly and with difficulty. And the parts of the hand near these sores assume a death-like hue.

The chemist is reminded by these and many other facts, that by his art, he removes the veil, under which the ultimates of the origin and end of material forms lie hid: the beginnings of whatever is assuming a determinate corporeal existence, and which cannot unfold itself, without destroying, so far as its power in relation to the same extends, that which has already taken form, when it comes within its vicinity. There is even in water (ch. 23) a constituent, which, by its polaric state, is

kept in such happy harmony in this element that, in this combination, it serves to nourish all living creatures. This constituent, known as hydrogen gas, gives for the most part, to fruits their flavor, to wine its exhilarating power; it is an indispensable ingredient in most of the articles of food that we relish. Nevertheless, hydrogen gas, when it is freed from its connection with water, and comes forth as a pure primal element, becomes a fearful power; mingling with atmospheric air, it kindles like gunpowder, and shatters everything around it. Even in its more unusual combinations with carbon, phosphorus, and sulphur, it forms different kinds of air, which, being inhaled, are injurious to life; in an unmixed state, if taken into the lungs, instead of common air, it suspends the vital powers. There is a higher order of being and of continuance in being, in accordance with which all individual, material existences are united to subserve the maintenance and continual renovation of the whole. By his art, man can change that higher order, and release the elements from the laws to which they are subjected, but these emancipated forces are no longer, as in their previous combinations, in the service of life, but of that dissolving force, which oftentimes extends its contagious influence to the elements of a living body coming within the sphere of its action, releasing them also from their subjection to the laws of life and its constructive agencies.

Of the release of *Chlorine* from that union with sodium, which, as common salt, is almost an indispensable article of human economy, we have spoken generally above. When a mixture of common salt, manganese ore, and sulphuric acid, diluted with water, is exposed to heat in a retort, the sodium is united with the oxygen gas of the manganese, and an oxyde is formed, the mineral alkali, soda, which is immediately taken possession of by the sulphuric acid, while the chlorine, excluded from its possession of the metal by the more powerful

acid, appears as a greenish yellow vapor. Although a burning wax-light, introduced into this vapor, continues to burn on with a smoking flame, yet this gas is very dangerous to man and beast who inhale it, and, if it is mixed with atmospheric air, the inhalation of such a mixture produces violent spasms of the wind-pipe, and oppressive pains in the breast. Many combustible bodies, and even most metals, are ignited, when exposed in a pulverised state to chlorine gas, and combine during their combustion, and form chlorides. While many of the above-mentioned properties remind us of those of oxygen gas, chlorine gas resembles also vital air, in that, being mixed with hydrogen gas, it forms an explosive gas which explodes with violence on being exposed to the sun's rays. Under the effect of a weaker light it unites gradually with the hydrogen and becomes colorless hydro-chloric acid gas, which is taken up with extraordinary eagerness by common water, and forms with it one of the strongest acids, Muriatic acid. This acid is obtained, by decomposing common salt with sulphuric acid. Our own, living bodies require no such arrangements. In its hidden laboratory, the animal system releases the chlorine from common salt, and uses it as an ordinary component part of the gastric juice, for the decomposition of our food, in states variously indeed combined.

Of incomparably less importance than chlorine are two other bodies, ranked also among the elements or simple substances, and having the sea for their special dwelling place: *Bromine* and *Iodine*. Bromine, although only in quite small quantities, is found united with the salt of sea-water, and is, like Iodine, obtained also from the ashes of some sea-plants. At the ordinary temperature of the air, this substance forms a fluid, whose easily disengaged, offensive vapors, are considered as useful as chlorine in dissipating the infectious influences of animal substances, and other miasmata which are contained in the atmo-

sphere. Iodine is found in various sea-animals and sea-plants, and in some mineral springs; it shows itself through the influence of heat as a violet blue vapor, that, upon cooling, forms small, steel-gray crystals, shining with a metallic brightness, and which, when moistened, evaporate emitting a smell similar to that of chlorine. In larger doses Iodine acts as a poison, while it is used as a medicine without injury, in goître, for example. The combustible base of *Boracic acid*, also called by the chemists *Boron*, has in the lower material world a very limited diffusion and influence.

Quite different is the case with the base of that earth, which forms indeed the predominant constituent of our mountains, the base of *Silica*. This appears as a dark brown powder that does not admit of fusion, but is inflammable in the air, and burns with a lively flame. The oxyde, thus produced, although it has no acid taste to the tongue, has all the other qualities of an acid, and would on that account be more correctly called silicic acid than silica. As an acid, silica unites with the most diverse earths and alkalis, and a great part of the different species of rocks belong among these combinations. As previously remarked, man has, from primitive times, availed himself of this relation of silica to other substances, for purposes of practical life, manufacturing by the melting together of silica with alkalis, glass, by mixing the same with lime, mortar, and by combining silicious substances with clay and lime, producing all sorts of fire-proof or stone-ware vessels for the kitchen and the cellar. Silica is found also among the elements of the human body, although in very small quantities, especially in the hair. In different vegetable bodies it occurs much more frequently and more widely diffused.

22. SULPHURIC ACID AND MURIATIC ACID.

In a small country school, a school director asked the boys what is the use of the air, what purposes did it serve in nature. One of the boys who were questioned was readiest with an answer, and he said: It serves to cool things. A second said: To blow the fire. And when the questioner was satisfied with neither of these answers, a third said: The air drives the sails of the wind-mill round, where the corn is ground for bread. A fourth brought an answer from a yet greater distance, and said: The air moves the ships on the sea. Not one of the young people thought of that office of the air which lay nearest to them, and which is the most important. They did not consider that, without air, all nature would be cold and dead. Only by means of the air does the sound of bells become perceptible; above, at the greatest heights which man has reached, where the air is very rare, the human voice, at the distance of only a few steps, is no longer heard, and the discharge of a pistol gives only a faint report; and in a perfect vacuum, the sound of a bell cannot make itself audible. But the loss to the ear, if there were no air round the earth, would be the less evil. The eye too would suffer, in more ways than one. Were there no atmosphere, there could be no twilight, morning and evening, coming, as it now does, from the light of the sun, reflected by the air. In the morning, at sunrise, daylight would suddenly break upon the dark night, without announcing itself, and at evening, when the last point of the sun's rim sank below the horizon, daylight would vanish without farewell, without casting one friendly look upon us at parting, from the golden clouds and the evening-red, leaving us instantaneously, and the darkness of the night would come in like manner, so that the wanderer on mountain ways would have to pause at *sunset, without* taking another step. And even this would not

be the most terrible consequence, which must follow the withdrawal of the air. The air, and above all, that substance contained in the air, which we have often mentioned, and which we propose to consider more particularly, oxygen gas, has for everything that lives and moves on earth a yet more essential use; without air there could burn neither fire, nor lamp. And not indeed in the sense, in which the boy meant it when he said that the air served to blow the fire, but because the oxygen of the air is just as necessary to the warming and illuminating flame as the rising of the sun is to the light of day. If no sun poured its beams down upon our world, we should have no day; if the oxygen did not rush with its inflaming power, into the mass of the combustible body, in order to unite itself with it, there would be no light for our chambers, no fire for our hearth, from hops and malt no beer could be made, from the juice of grapes no wine, and no vinegar from any of the productions of nature. But this is not all. Were the air taken from us, especially the oxygen gas, which is in the air, it would be all over with you and me in a few moments; not a frog nor fish, neither the badger in his hole, nor the bird in the air could live a moment. And not only the oxygen,—but even if the other gas of the atmosphere, nitrogen, were taken away, we and other living beings could not subsist. For in the flesh that we eat, and in the bread that nourishes us, and in the milk that the child takes, in most of the drinks, with which we are all refreshed, nitrogen is quite an essential, forming element.

Thus besides cooling things, and blowing the fire, and turning the windmills, and impelling the ships, air serves yet very many other purposes.

But not merely when we ask about the uses of the air, are we likely to receive such unsatisfactory answers. Still more strikingly would this be the case, if one were to inquire about

the uses of certain other substances. If, several generations ago, one had asked even a learned man, and not the mere pupil of a country school, of what use Soda (natron) is in the material world, he would scarcely have been able to indicate, in his reply, any other important uses than those we have already mentioned, the making of Glass and Soap. But since Chemistry has ascertained that soda is a component part of common salt, which is one of the most important elements, not only in human economy but in all nature, a quite different and much more comprehensive answer may be given to the question just proposed.

In speaking of the principal properties of some of the acids mentioned in the foregoing chapter, we would not forget a man who made a somewhat strange, but nevertheless happy, use of his rare gifts. This was the German physician, John Rudolph *Glauber*, who was born at Carlstatt, in the year 1604, and who ate the bread of many masters, traveling first to the Netherlands, but planting his pilgrim's staff in other quarters, residing now in Salsburg, and then in Frankfort on the Maine, in Kitzingen, in Cologne, and in many other places, and at last finding a resting-place for his weary limbs in Amsterdam. In his experiments in alchemy, which aimed at nothing less than the discovery of the art of making gold, and of the elixir of life, Glauber formed so intimate an acquaintance with several of the most powerful acids, that, by their help, he opened to science more than one before hidden depth. We will gladly pardon this singular man, that he allowed himself to be somewhat carried away, like many others of his cotemporaries and associates in art, by a hankering after the fruit of the tree of life, the panacea that was to conquer all diseases and even death itself, the philosopher's stone, "by which gold may be made from other metals and substances." For although the tree of life remained guarded against his hands as well as the hands of

other men, yet in his wandering in search of it, he found, by the sweat of his brow, many a useful thing. His merits, in regard to chemistry, extend to the improvement of the chemical furnace; his sagacious mind discovered various ways and means of lightening and rendering more profitable the labors of the chemist. Among the substances which the chemist needs for his services, concentrated sulphuric acid, or oil of vitriol, was one of Glauber's most trusted favorites, with which he was wont to accomplish much. Among other things he poured this strong acid on common salt; there arose a very remarkable degree of heat, the vitriolic acid possessed itself of the alkaline base of the salt, but the chlorine, combining with hydrogen gas and becoming muriatic acid, escaped in the form of vapor. After this expulsion of the strong by means of a stronger, there remained to the busy man a salt, generated by his art, sulphate of soda, which he used against many of the annoyances and suffering of human life with such success, that he as well as others named it "wonderful." It is still held in honor and use as Glauber's wonderful salt ("*Sal mirabile Glauberi*,") and many of my young readers probably know its good and bad qualities by personal experience.

We have here come upon one of the uses of Sulphur and its acid, of which indeed we have already spoken in passing, but which we will now consider more fully.

To a question in regard to the use of sulphur, many of our country people, old as well as young, would return as unsatisfactory answers as were given at the above mentioned examination concerning the uses of air. There would not be wanting those who know no use of sulphur for practical purposes, but that matches are made of it, that the casks, in which wine, and in many places beer, is to be kept, are cleansed by sulphur, or that this substance is used in the preparation of gunpowder. To these uses of sulphur many better instructed

would add, that sulphuric acid is used in coloring, to dissolve indigo, and in the preparation of alum and blue vitriol, and by the purifiers of oil to get rid of the scum. To some also it would be known that soda is obtained, as we have already stated at length, by means of sulphuric acid, for the fabrication of soap and glass.

Yet after all, we have mentioned only a very small part of the uses made by human art of sulphur and sulphuric acid. In the subterranean realms of nature, especially in regard to metals, it occupies the place of that sovereign among the substances i. e. of oxygen gas, of which we shall shortly speak more at large. Just as a combustible body burns in oxygen gas, in like manner, a silver or copper-plate as well as an iron wire with a clear flame, when exposed to the vapor, which is formed from sulphur in a closed vessel at a heat of 114 degrees Reaumur, 256. 5. (Fahr.) Put sulphur on red hot copper or iron, the metal, so hard to be fused, immediately begins to melt, and trickles down, like wax from a candle.

But although sulphur plays among metals the imperial office of oxygen in the whole kingdom of substances, it submits itself willingly and easily to this yet more powerful master. It takes to oxygen the relation of a combustible body, and both united, sulphur and oxygen, form a power, to which chemistry is indebted for its greatest victories, for most of its achievements in the world of matter. Not only muriatic acid, most of the other acids also, especially nitric acid, would never have come within the power of man, or at least not so easily, without the help of sulphuric acid, which separates its weaker sisters from their associations with other substances. The most singular effects are produced in art by means of sulphuric acid; even a conversion of starch, and many other organised substances, into sugar, is effected by the use of this same acid. What were chemistry, what most of the trades, from soap-boiling up to the

working in the precious metals and the purifying of gold, without sulphuric acid?

In the preparation of this important substance, no people have done so much as the English. We sometimes hear the proverb: *Amsterdam is built on herrings*, in allusion to the fact that Holland owes her early prosperity to the herring fishery, and to the skill of her people in salting and selling them. In like manner one might say that the flower of England's manufactures and trades has grown for the most part out of those gigantic Lead chambers, in which sulphuric acid is prepared. When, some time ago, the Neapolitan government thought to prevent the purchase of sulphur in Sicily, by the establishment of a monopoly of the sulphur trade, it came near producing a war between England and Naples. The pure sulphur, which is found in the greatest quantities in Sicily, was carried in whole shiploads to England, and was there consumed with such advantage, that, from one cwt. of sulphur, three cwt. of sulphuric acid were obtained. This, used merely in separating soda from common salt, (ch. 19,) gave the glass and soap manufacturers such an impulse that the English were enabled with their cheaper products to supply Portugal, Spain, a great part of America, Egypt, Turkey in Asia, Persia and India.

But to the above named countries, England furnishes not only soap and glass, but for them and many other countries, her enormous machinery spins, and her ingenious factories weave, press and color an immense quantity of woollen and cotton goods. The bleaching of these goods is a very essential part of their finish and perfection. The common mode of bleaching is to spread out and expose the cloth, made out of vegetable fibres, to the sunshine and the air, while it is kept moist by constant wetting. If we wish to know exactly what effect this process has, we have only to expose any piece of our manufactured textures to the same influences for a longer

time than usual. We shall find that it continually loses in weight until its fibres give way and it resembles the loose texture of paper, rubbed to pieces by the fingers, until at last it falls apart and is scattered by the wind and rain. Every rag of worn-out cloth or linen, when acted upon by air and moisture under only a quite moderate heat, will satisfy us, by its gradual decay, that the fibres of flax or cotton are just as much subject to dissolution as mouldering wood. We shall by and by seek to show that carbon, which is the principal ingredient of the vegetable fibre, is steadily combining, when favored by air and moisture, with the oxygen, and that in this way, no less than by fire, carbonic acid is formed. In the ordinary bleaching of our stuffs, therefore, we take to our aid a power, whose effect is indeed at the first slowly destructive, but which nevertheless serves our purpose, because those natural impurities, and admixtures, which are already in the process of decomposition, and which give the fibre a dirty color, are first attacked and removed, whereby indeed the cloth itself suffers some loss, perceptible in the diminution of its weight. That this cleansing influence may have its due effect, weeks and even months are needed, and space is required according to the size and number of the pieces of cloth which are submitted to the process. For our domestic economy the means of bleaching are sufficient, but what would the manufacturers do, who have to weave and bleach, not for single families or even for a single country, but for whole nations and regions of the earth? What would be the price of a bleaching ground upon which 10,000 pieces of cotton goods were to be spread out for months, in populous England where every square foot of soil is in use? How high would the wages go for the laborers who were to tend all these pieces and keep them wet? But the same amount of goods is bleached (*Liebig's* chemical letters, p. 107,) in a bleachery near Glasgow, in less than eight days, and upon an

eighth of the space; for those factories bleach 1400 pieces per day, and besides can be carried on, not only in summer, but in winter also, when the ordinary mode of bleaching must be suspended.

Is it asked what has procured for the English bleacheries this extraordinary advantage? The answer is: The art of bleaching so rapidly, and at the same time so perfectly, would not have been learned without the art of preparing sulphuric acid. When in the process of obtaining soda from common salt, four parts in weight of concentrated sulphuric acid are added to five parts in weight of common salt, there is formed, from the union of the sulphuric acid with the soda, the salt already mentioned, and taking its name from Glauber. But in this transfer of the soda, which is formed from the oxydation of the metallic sodium, to the sulphuric acid, the chlorine is released from its previous combination with it, and, united with the hydrogen, forms hydro-chloric or *muriatic acid.*

The chlorine gas, of the destructive properties of which we have spoken, was formerly let off from the conduits of the factories, oftentimes to the great injury of the neighboring vegetation. Soon, however, man learned to convert this hostile power into a friendly one, taking it into his alliance, when other and more injurious substances were to be speedily destroyed. That formidable poison, oftentimes not at all perceptible to our senses, which is generated as contagious matter (miasma) in hospitals, where numerous patients lie affected with malignant fever, the miasma of pestilence, the exhalations, rising from the pits in which the dead are thrown at times of great mortality,—all these destructive forces, against which human art formerly availed nothing, we have learned how to conquer by means of the vapors of chlorine. In its own gaseous form, it pursues gaseous organised vapors wherever they are to be found, and, by taking from them their hydrogen, deprives them of their power.

Chlorine acts still more remarkably upon those coarser substances, which, in the form of dirt, attach themselves to goods woven from the vegetable fibre, to our linen, cotton or woollen cloths. Wherever its vapors meet such admixtures, they dissipate them with extraordinary rapidity. It pursues substantially the same process of destruction as the light, the air and the water upon our bleaching grounds, but it is more under our control. Chlorine may be kept and sent to great distances by being combined with lime, as the so-called chloride of lime, and it is sent far and wide from the soda factories to the bleacheries, to which it has rendered great service in the ways we have mentioned. In a few hours, and besides, at a much less cost, cotton stuffs are cleansed of all those discoloring substances that adhere to them, by means of chloride of lime and its solutions; and under this mode of bleaching, the cotton suffers much less than by the old process; so that, here and there, even the country people use chloride of lime for bleaching.

Among the many uses of muriatic acid, *Liebig* (Chem. letters, p. 108,) mentions one, which could not have been thought of before the acid was so easily procurable. The bones of animals, estimated by weight, consist of about three parts of phosphate of lime to one part of animal gelatine or glue. When bones are put into muriatic acid, diluted with water, the acid immediately dissolves the bone earth or phosphate of lime, and leaves the glue combined with it, in the shape of the bones, as pliant as leather, and after being cleansed from what remains connected with it of the acid, the glue can be used like any other glue. So that muriatic acid is of extraordinary utility to workers in all kinds of substances from the metals down to refuse bones. But only by means of sulphuric acid has it come into this universal use.

This acid, (sulphuric acid,) which in many respects may claim the rank of queen among all other acids, was first

obtained in Germany, from an iron ore found in almost all our mountains: the sulphuret of iron (pyrites,) which we are yet to speak of, and which consists of about five parts iron with six parts sulphur. In the places where this sulphuret of iron has been brought out from the mines in great abundance as at Gorslar, in the Harz mountains, and in Bohemia, it was placed on grates, over a fire. In the long continued heat, a part of the sulphur was consumed, and a part of the iron formed with oxygen the red oxyde of iron. The ore, thus roasted, was heaped up on strong floors, somewhat inclined, and exposed for several years to the air, rain and snow. Gradually there was formed sulphate of iron or green vitriol, which, easily soluble in water, was led off by the rain through gutters into reservoirs from which it was frequently poured anew over the roasted ore, until the solution attained a certain strength, when it was evaporated in kettles over fire, and then first was obtained the green harsh-tasting vitriol, which is used in many ways for coloring. From this green vitriol, sulphuric acid is obtained by means of heat. By evaporation kept up over fire, sulphuric acid is more and more freed from the water combined with it, and is thus made very strong. But the sulphuric acid, obtained in such a troublesome and tedious way, could not supply the demand in Europe, and especially of the English, although the vitriol works at Beierfeld alone, in the Saxon ore-mountains, produce yearly upwards of 1400 cwt. of sulphuric acid, or oil of vitriol.* Far less abundant was the sulphuric acid obtained in the same way in other countries. Hence that first experiment, which, it is said, was made by a German immigrant in England, by the name of *Moeller*, to generate the acid by a speedier progress, from the pure sulphur, must be considered as the beginning of a new impulse given to the activity of trade.†

* This acid is generally known as the Nordhausen sulphuric acid.

† The credit of this method is more generally accorded to Dr. Roebuck, at Prestonpans.

Wonder, mingled with a sort of horror, seizes the stranger, who, for the first time, looks into one of those gigantic lead-chambers, and, so far as may be, sees how the suffocating sulphurous vapor is transformed into the acid. Man appears here to be contending with the powers of a volcanic crater. Spaces are presented 120 feet long, 40 broad, and 20 high, and even still larger, in which a two storied house of moderate size might be put. These enormous chambers are lined entirely within with leaden plates, soldered closely together with lead; on the floor below stands water several inches deep. The sulphur is consumed on a stone plate in the chamber itself, or in a furnace beneath, connected by a tube with the chamber. But the combustion of the sulphur gives only sulphurous acid, to which a large proportion of oxygen gas must be furnished to make it properly sulphuric acid. And this it receives through the right of the stronger over the weaker. In the same furnace with the burning sulphur is placed an iron pan, containing about a tenth of nitrate of potash, (common saltpetre) or nitrate of soda, mixed with sulphuric acid. The sulphuric acid liberates the nitric acid from its combination with the potash or soda, which, coming in contact with the sulphurous acid from the burning sulphur, is reduced to nitrous acid by the sulphurous acid, which takes a portion of its oxygen, and becomes sulphuric acid. The nitrous acid is again deprived of another portion of oxygen by a fresh portion of sulphurous acid, and is reduced to nitric oxyde, the sulphurous acid becoming sulphuric, this nitric oxyde now coming in contact with the air of the lead-chamber, takes oxygen from it, and becomes nitrous acid again, which is again reduced to nitric oxyde by the sulphurous acid, which is transformed into sulphuric acid, which combines eagerly with the vapors of the water, and trickles down from the *ceiling and* walls into the water on the floor of the chamber, *or of the* adjoining chamber. Now, however, an impor-

tant point remains to be accomplished by chemical art: the evaporation of the water by a high degree of heat, and the ultimate production of sulphuric acid in its greatest possible strength, and free from water. Here platinum comes into honor and special use, which it deserves above all other materials of which chemical apparatus is made. This metal is not melted by the heat that tears away from the sulphuric acid the water which it holds so powerfully; even the strongest sulphuric acid is not able to affect it, on which account the proprietors of sulphuric acid works have no hesitation in paying for a single still made of this precious metal, 10 or even 20,000 florins, for as (according to Liebig's statement,) some of these manufacturers produce 60,000 cwt., and even those of middle standing, 20,000 cwt. of sulphuric acid in the course of a year, the capital employed brings in a high interest.

We, of the present day, enjoy at a cheap rate a superabundance of conveniences which our fathers were unable to procure for solid gold. We owe our advantage in great part to sulphuric acid, and to its power over other substances. As is the rapidity with which we now produce a flame by merely rubbing a match, of which sulphuric acid furnishes the material, compared with the old way, by steel, flint and tinder, so is the ease, with which many of the most important pursuits are now carried on, compared with the methods of former times.

23. CHEMICAL POLARISATION.

Powerful as is the force which moves sulphuric acid when mixed with common salt, to combine with the soda, and preponderating as the attractive power of this acid shows itself over the force of the muriatic acid, there is nevertheless a means of again drawing away this victorious agent from the possession which it has seized so firmly. Yet is this possible

only in the ordinary way: by offering to the sulphuric acid another substance, to combine with which it has a still stronger disposition than with the soda. This is effected by acting on Glauber's salts or sulphate of soda, by the vegetable alkali or potashes. Exactly as in the way mentioned of refining silver, the sulphuric acid lets go the silver with which it is united, and sinks into union with the copper, so the strong acid gives up its possession of the soda and seizes the alkali, whose carbonic acid now associates itself with the soda.

Following Liebig, we must here say a word respecting a mode of speech, some time since introduced into the domain of Chemistry.

In two magnetic needles, those ends are unquestionably related in their nature and properties, which have both the same direction north or south. Nevertheless these similar ends do not mutually attract, but repel and avoid one another, while those, whose direction is directly opposite, the one to the other, seek to attract each other and unite. Just so we remark also, in the chemical intercourse of substances, that in a solution composed of various elements, one acid does not attract another and combine with it, nor one alkali another alkali, but rather those substances unite with one another which are of a wholly opposite nature and character: the acids with the alkalis or alkaline earths, and the reverse. Of that mutual repulsion and avoidance of similar substances, which may be compared with the repulsion of the corresponding poles of two magnets, the processes which we have described, afford several remarkable examples.

For this reason, the common expression, which designates the associated action of substances polarically opposed, the acids and alkalis, as chemical affinity or relationship, and describes the greater or less strength, with which a substance seeks to be combined with this or that other substance, as

nearer or remoter degrees of relationship, must be understood in another sense than that which we connect with the word, affinity or relationship, in common life. The children of the same parents, resembling one another in their features and characters, are related; there is a natural affinity between them; such as are of different families and races are not similarly related. If one would use the word in the same sense in reference to the substances and their combinations, then he must consider the acids as near relatives, and just so again with the alkalis and alkaline earths. That, however, which lies at the bottom of this tendency to chemical union and gives it its peculiar strength, is not a common descent, and near agreement of powers and properties, but directly the reverse. The farther in this respect, substances stand removed from one another, the stronger is the tendency, which, under favorable circumstances, leads to their union, and as, on the other hand, the fall of a body from a less height is less forcible and swift than it is from a greater, so the mutual attraction of substances grows weaker and weaker, the nearer they approach one another in their peculiar qualities.

There is here, moreover, something that reminds us of the natural relations that stand nearer to our own being. The friendship of man for animals can never be so great as that of man for man, (or as that of animals for their own kind.) Thus oxygen gas and hydrogen gas stand, in their properties, at a great distance from gold and platinum, but in these opposites there is no natural disposition to union, while gold on the contrary easily enters into combinations with mercury, oxygen gas with carbon, when the latter has, by means of the forces of organized life, approached nearer the gaseous condition, or with the quickly evaporating phosphorus and sulphur.

The same substance, which may stand in relation to another substance as an acid, in relation to a third substance, oftentimes

The substances, which principally form the organised body
he vegetable and animal kingdoms, are four: *carbon*, *hydro-*
, *nitrogen*, and *oxygen*. We shall consider here, first,
y the first two, devoting to the latter two a special chapter.
Only rarely is carbon found pure and unmixt, and the pro-
ties, which it then presents, are so remarkable, that, from
earliest times, they have arrested attention. The purest
n in which carbon appears, namely, as diamond, gives to
golden crowns and diadems of princes their highest value
l brilliancy. That coal and diamond are in substance one
l the same,—what wise man of antiquity would have held
s apparent contradiction for truth! Nevertheless, so it is.
e diamond, this hardest and most solid of stones, with the
arp splinters of which, even the sapphire can be cut, and the
ooth surfaces of which, even the hardest English file cannot
fect, the diamond cannot resist the heat of the sun's rays
ncentrated in the focus of a reflecting mirror; it is consumed
ith a faint light, and is dissolved into carbonic acid, through
s combination with oxygen.

That, which gives to carbon in the form of diamond its
egular form, its wondrous brilliancy, its extraordinary hard-
ess, is the power of crystallisation, which it is no more in our
power, through art, to give to the coal which we burn, although
we obtain the carbon from it in the greatest possible purity,
than it is to give the powers of life to those elements, of which
a body, just a moment ago living, but now dismembered by our
hands, consists.

The substance of coal (carbon), so to speak, takes a crystal-
lised state, with extraordinary difficulty and only under condi-
tions of which we are ignorant. This fact is especially favor-
able to organic life; for if this substance could be as easily
converted into diamond as chloride of sodium into rock-salt,
arbonate of lime into little crystals of calcareous spar, or

iodine into its peculiar crystalline forms, what power of digestion and decomposition would then suffice to draw the indispensable means of nutrition within the circle of life and growth!

One of the commonest and most abundant forms, in which carbon presents itself, as a component part of the earth, is *stone-coal*. When in some kinds of the same, among which the shining coal (anthracite) belongs, carbon predominates in greater purity; these kinds of coal prove to be vastly more difficult of combustion than those ordinary species of black and brown coal, in which the carbon is combined with bitumen which abounds in hydrogen gas and oxygen gas, and partly, as in charcoal, in metallic substances, the alkalis and earths. Beds of stone and brown coal (peat) are found in all quarters of the globe, in the farthest north, where scarcely a straw flourishes, and in the countries of the torrid zone with their luxuriant vegetation. England alone produces yearly about 150 millions cwt. of stone coal, whose value is estimated at 48 millions of guilders, and 150,000 persons are employed in its coal trade. The consumption of this article is everywhere considerable, and it has been reckoned, that supposing the coal of England to continue to be mined at the same rate, it could be exhausted in 350 years. Should it really happen so, the still hidden vaults, in which this treasure is stored and which elsewhere exist, would soon open to man, the ruler and investigator of the earth.

In other forms also than in that of stone coal, is carbon found among the component parts of the earth, namely, as bitumen, petroleum, naphtha. There are places, where these inflammable, solid, or fluid substances, come forth of themselves from below, as in the springs of petroleum and naphtha, which exist on the western side of the Caspian sea, and in the Birman Empire, whose inhabitants, without any trouble, yearly

collect petroleum to the amount of 400,000 hogsheads. Also on the surface of the Dead Sea, asphalt (pitch) is frequently found in floating masses and fragments. Among those fossils, which are rich in carbon, belongs also amber, a production of the antediluvian vegetable world.

Carbon, in union with oxygen, and forming carbonic acid, is found still more extensively diffused, and possessing a greater activity, than the above named forms of combustible fossils. The by far greatest part of our lime mountains consists of a combination of carbonic acid and lime. The water of our springs very generally contains, and in part in sufficient quantities to be perceptible to the taste, the carbonic acid, which here and there, in a vaporiform state, fills the hollows and depths of the earth. Even in our atmosphere, carbonic acid is indicated as one of the more uniform constituents, although its quantity, in comparison with the principal gases of the air, is very small. It is distinguished from the other gases of the atmosphere particularly by its much greater specific gravity, by reason of which it collects, wherever it can do so, at the lowest points.

To the breathing animal, carbonic acid, in a gaseous form, is fatal. After a few inhalations the animal is suffocated; and the flame of a burning candle is extinguished in this gas. On the other hand, when it comes, united with water, within reach of plants, it contributes in an especial manner to their life, the plants taking up the carbon as nourishment and exhaling the oxygen combined with it, when the sun shines on their green leaves. Animals also, and especially man, takes no food, whose truly nourishing power is not to be ascribed particularly to the carbon, which it contains, united with nitrogen and hydrogen. There is no part of the human body wholly without carbon; every breath that we draw, every pulse of the blood receives the impulse of motion from the egress or ingress of this sub-

stance, because, in the higher circle of created existence, it serves to keep up the fire on the altar of life, as coal keeps up fire on the hearths of huts and palaces.

Water, in its all-nourishing, all-supporting office as nurse and house-mother, we have already considered (ch. 3). Many of its properties have been known in earliest times. It had been declared, as a sort of prophecy, that water can be produced from air, and become air again. But there is a great difference between such a surmise of the human mind and actual knowledge, founded on sure experience. How quickly is the flash of a cannon, discharged at a distance, visible to the eye, and how much longer is the interval before the sound of the report reaches the ear; just so the prophetic thought of the mind, the intention directed to any act, exists in us at once, but the realisation of the thought, by actual inquiry and experiment, has for the most part still a long way to pass through manifold difficulties and obstructions, to reach its consummation.

Water actually consists of air, but not of one kind, but, as it has been made to appear since the year 1766, by *Watt*, and the chemists *Cavendish* and *Lavoisier*, of two kinds of air, into which it can be separated by human art, and of which it can anew be composed. With the fact, with which every child may be acquainted, and according to which water presents itself as the readiest and most natural means of putting out fire, hardly anything could stand apparently in more direct contradiction than the discovery, that in water itself exists a substance, inflammable and burning with a powerful flame. But when water is separated into its two opposites by electricity, in other words, polarised, then is obtained the *inflammable air*, of whose destructive force we have spoken (ch. 21). Miners, especially in coal-mines, are familiar with this under the name of fire-damp. It has destroyed numbers, shivering them into pieces by its explosive power, similar to that of gunpowder,

and similar effects have been produced, when in cellars or other close places, in which vessels of fermenting fluids were kept, inflammable hydrogen has been developed by the process of fermentation, combined with carbon. To spirits of wine, as to oil and all fatty or resinous bodies, inflammability is given by hydrogen in union with carbon. Carburet of hydrogen affords us the material for lighting our houses and streets. On a yet larger scale, it is made to furnish fuel to those natural hearths, where fire is always kept going, and which exist in the neighborhood of naphtha springs and of many salt beds, by merely boring into the earth and lighting the gas which issues therefrom.

Besides electricity, by which in fact the purest hydrogen gas is obtained from water, there are yet various other means at our command of procuring inflammable air with ease and in tolerable abundance. The element, which oftenest holds it and draws it to the ground in the form of water, is *oxygen gas* or *vital air*, the sovereign among all the substances known to us, furnishing the basis in all chemical combinations, in all physical formations, for whose society and alliance, most other substances manifest a lively desire. For while gold, for example, stands, like a hermit, amid the primal elements of the upper world, and voluntarily enters into union, neither with water nor air, but only with its fellow inhabitants of the subterranean world, as with mercury, for instance; the easily rusting iron, copper, and most other metals seize opportunity to abstract the oxygen from the water or the air and to become oxydes. When water, to which about a fifth or sixth of its weight in concentrated sulphuric acid is added, is poured upon iron filings or pulverised zinc, the acid produces a polarisation or decomposition of the water, similar to that produced by the electric spark, the disposition of one pole to union with the iron becomes so much increased, that, with the iron, it presents the oxyde, and in the same proportion, the opposite polaric action is increased

also, which exists in the nature of the water, and there is produced hydrogen gas, which, in combination with carbon, of which almost all iron contains a small proportion, rises from the water.

When the two kinds of gas, produced by means of the polarisation of water, are compared in reference to their weight, it is found that oxygen gas weighs 8 times more than hydrogen. To speak exactly, the proportion between them, in this respect, is as 8891 to 1109. But when the space is considered, which both occupy in their gaseous form, it is observable that the hydrogen fills double the space held by oxygen, so that a cubic foot of hydrogen is 16 times less in weight than a cubic foot of oxygen. When, therefore, water is to be combined from these two gases, eight times the weight of oxygen must be joined with once the weight of hydrogen, or, if the space, which they respectively occupy, be regarded, a volume of hydrogen must be employed double that of the oxygen. When mingled in this proportion, and a burning light or spark is brought near to the mixture, it is inflamed with a violent report, and so suddenly expanded by the heat generated in the combustion, that the vessel, in which the combination takes place, if of a fragile nature, is shivered into atoms.

The influence exerted on water by electricity, which, after all, is only a faint type of the vital force which reigns in animated beings, is exerted also much more generally in the sphere of organic life: here the water becomes polarised without ceasing, indeed so, that each of the two polaric substances is immediately used for the fashioning of the fluid or the more solid parts. In every, even the smallest part of the human body especially, hydrogen is contained at the same time with the carbon already mentioned. But in addition to these two, there are yet other two substances, by the mixture of which particularly is formed the atmosphere that encompasses our planet on

all sides. But in passing to a more particular consideration of the constituents of the atmosphere and the properties of the same, a brief notice of aerial navigation will afford us an opportunity to take a general glance, as a bird might, at the atmosphere, and at some of the formations which are going on in it.

25. AERIAL NAVIGATION.

An iron anchor let down into the sea immediately sinks, drawn by its own weight into the flood below, and drags down with it even the cable to which it is fastened, until it reaches the firm ground which will not let it sink any deeper. The water of the Dead Sea, by virtue of the many saline parts which it contains dissolved in it, is so thick and heavy that a man, who has never learned to swim, can keep himself up upon it without any trouble, while a piece of chalk, although its proportionate gravity is much less than that of a pebble-stone, sinks in the same water to the bottom. But even a piece of iron does not sink in fluid mercury, but floats thereon as easily as a piece of cork on water. As a little piece of elder pith, loaded at one end with lead, to the amusement of our children, always takes a position with the heavy end down and the light end up, so in all fluids, the body which is lighter than the fluid rises, and that which is heavier sinks to the bottom.

The art of traveling on water was invented and practised in the earliest times; for the method of traveling thus was very obvious. The means of navigating the water were offered by the whole vegetable world, by almost every tree; for there are but a few kinds of wood, such as boxwood and magohany, so much heavier than water, that they sink in it. Most other kinds float, because the solid parts, of which they are composed, are not so closely and firmly united as the component parts of a

stone. Yet even a vessel made of iron, beaten out thin, floats on the water, because its cavity contains chiefly only atmospheric air, which is 770 times lighter than water.

The wish to sail about, not only on the water, but in and on the airy ocean of the atmosphere, must have often been awakened in man, when he saw the inhabitants of the air, birds and winged insects, hovering and flying about with so much ease in that element. To the birds especially, this is made possible, because their bodies within as well as without contain a multitude of cavities, which are filled with air, for the quills of their feathers, and even their bones, disclose such cavities, and, in the interior of their bodies, there are spaces connected with the lungs, which fill with air by means of the process of breathing. In addition to these facts there is the admirable arrangement of the wings and tail-feathers, which, when spread out, not only form a natural parachute, but their steering movement is preserved, effected as it is by the force of the muscles,—an arrangement, whose perfection human art has striven in vain to imitate. What, however, the hand has failed to accomplish, has been all the more successfully achieved by the imagination with its fabulous inventions; for as Dædalus and Icarus were said to have escaped from the prison of Minos, by means of waxen wings; so it was fabled also of a great mathematician of antiquity, *Archytas*, that he invented a wooden dove that flew in the air like a living bird.

These and similar fictions afterwards invented, nevertheless, found people here and there who held them for true, and were accordingly tempted to experiments which cost several of them their lives. Whether the Italian, Giovanni Battista Dante of Perugia, at the end of the 15th century, by means of his flying machine, really passed several times across the Trasimenian lake, ere he fell in attempting to take wing from a certain eminence, remains a question. At least the bold adven-

turer came off with his life, although he broke his leg, because fortunately for him he fell upon a tower; while a similar attempt to fly cost the learned Olivier de Malmesbury, in England, and Backwell, in Padua, their lives.

To swim in the water is quite a different thing from swimming in the air. The human body is not heavier, indeed it is a little lighter than water, while its specific weight is to that of the air almost a hundred times greater than that of iron is to that of water. In consideration of this fact, some learned men, as *Lana* in Brescia, and *Sturm* at Altdorf, (near Nuremberg,) the former in 1670, the latter in 1678, declared that the elevation of a solid, ship-shaped, body in the air, could be effected only by connecting with it hollow balls, weighing less than the air, and on this account rising in the air of themselves. The invention of the air pump by *Otto von Guerick*, twenty years before, appeared to furnish the means of carrying out this idea. For a hollow ball exhausted of air, if the material were not too heavy, must needs, so it appeared, ascend in the air. But of what should such a ball be made, in order to be strong enough to resist the enormous pressure of the atmosphere? This pressure amounts to 2,216⅔ lbs. on every square foot of the earth's surface; a thin metal plate is collapsed by it, and the thickest bladder, stretched over a vacuum, is burst in. Hence not altogether out of the way was the idea of father *Galien* at Avignon, stated in 1755, that such balls must be, not empty, but filled only with a specifically lighter kind of air, whose elasticity may resist the external pressure; adventurous as may appear the proposal, that the needed kind of air should be brought from the upper and rarer regions of the atmosphere. We are not reduced to the necessity of attempting such a trip, in order to fill the hollow balls or air-tight bags according to Galien's proposal with a gas, resembling common air in elasticity, but as much lighter than the air as water is in comparison

with mercury. The celebrated English chemist, *Henry Cavendish*, (born at Nizza, in 1731, died 1810, in London,) a man alike rich in mind and fortune, in the year 1766 discovered the great levity of hydrogen gas; and thus a new era was opened in the history of aerostation. Soap-bubbles filled with inflammable air, Kratzenstein saw in 1776 ascend with extraordinary swiftness into the air; *Cavallo's* experiments in 1782 failed, however, because silk paper let the air escape, and bladders were too heavy.

There yet remained, comparatively speaking, only a slight difficulty to be overcome, which lay in the preparation of an air-tight material, of which the balloon was to be made. This last remaining step was soon taken by two individuals, who, although not professionally men of science, have thereby won for themselves an enduring name in the history of inventions, the brothers, Stephen and Robert *Mongolfier*, proprietors of a paper factory at Annonay, in Vivarais. In the year 1782 they succeeded on a small scale, simply by means of heated air, in raising balloons to the height of the ceiling, and then to the height of a house; and these experiments, the simplicity of which would now excite a smile, created far and near a great excitement, and this excitement rose still higher when the brothers succeeded in preparing a balloon, tolerably air-tight, of linen, the inside of which was lined with paper, and the diameter of which was 110 feet. This balloon had an opening below, into which heated air passed from a fire, kept up below by straw and carded wool, set on fire. The comparatively greater levity of the air, rarefied by the heat, caused the balloon, when it was filled, not only to ascend, although its weight was 450 lbs., but also to carry up an additional weight of more than 400 lbs., and indeed with such rapidity, that in the space of 20 minutes, it reached a height of 6000 feet, and was carried by the wind, which that day (the 5th of June,) was not

very strong, a distance of three quarters of a league, when it fell to the earth.

The newspapers were full of accounts of this first victory, achieved by man over an obstacle, which places him below the bird; but a few months later, the public prints had much more important triumphs to tell of. Prof. *Charles* in Paris, availing himself of the aid of the brothers, Mongolfier, in preparing his balloon, which was made of taffeta, and rendered apparently perfectly air-tight by means of a resinous varnish, was the first to employ, instead of rarefied air, hydrogen gas, to fill the balloon, which was only 12 feet in diameter, and which, at the first trial, made August 27, 1783, on the Champ de Mars, rose about 3000 feet, then was lost from sight in the clouds, but after three quarters of an hour, began to descend towards the maternal bosom of the earth, and alighted five leagues from the place of its ascent.

Scientific men, and all the friends of the newborn art of sailing in the air, would have preferred that the balloon, like the dove let loose from the ark, should not have returned, but continued its course unseen by human eye—who knows how long? in the upper regions of the atmosphere, for thus it would have been proved that the sides of the hollow taffeta ball were sufficiently air-tight to permit no escape of the inflammable air, which must have the effect to cause the balloon to descend. To obtain this quality of impermeability, M. Romain of Paris employed a newly-invented varnish, by means of which, a balloon, which the brewer *Caps* made at Dantzick, appears actually to have resembled Noah's dove, for after being kept filled for three months with inflammable air, without suffering any diminution, upon being removed into the open air, it escaped from the light cords, by which it was held, and what direction it has taken over land and sea, no one knows.

As yet no living being had mounted into the air with the aerostatic ball, and the first, who enjoyed this honor could tell nothing of any experiments made during the air-voyage although a barometer was placed in their basket; for these first voyagers of the air, whom the younger Mongolfier caused to ascend on the 19th September, at Versailles, in the presence of the king, were a ram, a cock, and a duck. The excursion which these three took, by no will of their own, however, succeeded perfectly. They descended unhurt to the earth about a league from Paris. What the ram, the cock, and the duck had succeeded in doing, might safely be attempted by man. The first trial, however, was made with great caution. The balloon, which 4 weeks after the ascent of the aforesaid animals, rose with *Pilatre de Rozier*, a man of science, was held so firmly by cords that he ascended only to the height of 84 feet, and was drawn down again after a lapse of 4 minutes. A somewhat bolder attempt, made by the same gentleman 4 days afterwards, (Oct. 19,) was successful, although the cords of the balloon caught in some trees. The spirit for such an adventure now rose to such a height, that the Marquis d'Arlandes offered himself as a companion to the young Rozier, in the next somewhat bolder excursion, which was made on the 21st of November, from the castle La Muette, on which occasion the two adventurers were in the space of 25 minutes borne to a considerable height, and to a distance of nearly 3 leagues from La Muette. They came unharmed to the ground, and not a little delighted at the success of the journey. Their example instantly excited the emulation of others. *Charles* especially, who had been one of the first among the inventors of aerostation, and who was resolved not to be left behind in the application of the new art, now undertook (Dec. 1.) a voyage into the air, in company with one of the brothers Mongolfier, which, in its

splendid and successful execution, left all previous attempts far behind. The most distinguished point in the capitol, the Tuilleries, was selected for the ascent. Twenty minutes before two o'clock, P. M., the beautiful balloon, in a blaze of sunlight, and made of vari-colored taffeta, was seen to rise, carrying with it, hung by cords, a sort of triumphal car, in which the two cloud-stormers were seated. They soon rose to five or six times the heighth of the steeples of the city, and, at this height, of nearly 1800 feet, they surrendered the balloon to the moderate wind that was blowing, which bore them to a distance of nine leagues from Paris into the neighborhood of Nesle. Mons. Robert, having had enough of the cool journey, in order to cause the balloon to descend, opened certain valves, by which a portion of the light, inflammable air escaped, and an equal quantity of the heavier, atmospheric air was admitted. The balloon sank to the earth; Mons. Robert alighted on terra firma, and Mons. Charles, closing the valves, again rose. The balloon, now lighter by 130 lbs., rose once more to a heighth of 9000 feet, the heighth of the summit of Mt. Ætna. The annoyances of the icy coldness and rarefied air in that region of perpetual frost were outweighed, not only by the enjoyment afforded by the grand outlook over the country under the light of the setting sun, but even more by the thought that hitherto no denizen of earth had ever attained to so bold a flight. The car in which the happy mortal sate, had not in vain the form of a triumphal chariot; when after 5 and 30 minutes, it descended near a wood not far from Tour du Lay, and Mons. Charles disembarked unharmed and in fine spirits, the art of man celebrated one of its most imposing victories.

But now another man, one of the most fortunate adventurers of his time, appeared upon the stage, *Francis Blanchard*, who made a greater talk in all countries, than all his predecessors and companions on this new career of glory. Blanchard, born

1738, at Andely in the department d'Eure, was a mechanic by profession, and from his youth up had busied himself with all sorts of schemes and experiments, having for their aim, the invention of a flying machine. Without ceasing, asleep or awake, his lively imagination was practising the art of flying. At last, after laboring twelve years to realise his dream, he fancied he had succeeded. He went to Paris in 1782, some months before Mongolfier showed his balloon in that city, and first requiring money to enable him to prepare his flying ship, he announced in pompous terms his approaching excursion in the air, promising to rise into the highest regions of the atmosphere by means of the four wings of his strange ship. Arriving there, he would achieve an immense distance in a short time, would descend, here and there at pleasure, and even alight on the water, as his machine was to be so arranged as to be fitted to navigate the ocean. He was to dart through the air swifter than the raven, without losing breath, as he would be provided with a mask, ingeniously constructed to obviate that difficulty. Even against the wind, but only not in a storm, he would pursue his course, more slowly indeed, but nevertheless with greater rapidity than the best sailing ship with a fair wind.

This boastful announcement appeared in the widely-read *Daily* of Paris, and in thousands of ignorant heads awakened the liveliest agitation of interest and curiosity. The delirium spread among all classes; so that the great mathematician and astronomer, *La Lande*, considered it a duty to address a letter to the editor of the daily print, in which he abundantly showed the absurdity of Blanchard's scheme of flying in the air by mechanical means. The seducing influence, however, which the folly of one man, when it is accompanied with unusual self-confidence, exercises upon other men, manifested itself in this instance. Many indeed doubted, some sneered, while others, among whom was the engineer and engraver to the king,

Martinet, maintained the possibility of Blanchard's scheme, and were as anxious as the credulous mass to witness the proposed experiment. When the day came which the half foolish mechanic appointed to show his winged air-ship to the curious public, the crowd was so great and the space for the spectacle so small, that the affair had to be postponed. The universal curiosity was, however, to be gratified on another day, the 26th of August, and public notice was given by Martinet, that, if no serious obstacles intervened, Blanchard would ascend into the air before the eyes of all Paris. But such obstacles did actually intervene. Mons. Blanchard, having succeeded so well in raising the wind, on the appointed day, allowed much to be heard but nothing to be seen of him. The show-loving public might hold itself indemnified for its disappointed expectations by the sight of four copper plates, by Mons. Martinet, representing the adventurous air-ship in front and behind, outside and in.

Blanchard, with his boastings, retreated into oblivion, and he would scarcely have emerged again, had not the discovery made shortly afterwards by the brothers, Mongolfier and Prof. Charles, come to the help of this true child of fortune in the realisation of his dreams. Suddenly, after a number of air-voyages had been made by the help of the balloon, Blanchard, ever befriended by the wind, again appeared before the public with an air-ship of his own invention, in which, however, the balloon was the principal part, while it presented in addition a couple of wings on each side, a rudder, an anchor line, and below a huge parachute. The man was resolved to outstrip all his predecessors, not merely by ascending into the air, but also by going where he pleased in the sky like a bird.

Perhaps the accident that befel this artificial contrivance upon the occasion when it was first to be tried, in the beginning

of March 1784, happened not wholly inopportunely. A student who was resolved to press himself on Blanchard as a companion of the voyage, in his furious zeal broke the wings and parachute of the machine, and when Blanchard, nevertheless, prepared to ascend, provided merely with the rudder and the anchor line, the promised bird's flight was of course not to be expected of him. The spectators had to be satisfied with the assurance of the self-satisfied air-sailor that he would mount just as high as Rozier did, and that was 9000 feet. In the same month Blanchard delighted the inhabitants of Rouen with an air-voyage, when an accident again occurred, the wind breaking the rudder and leaving only the wings uninjured. Once again in Rouen, but several times afterwards, in quick succession, in England, he carried on his lucrative trade, and thus his confidence in his good fortune grew so, that he raised himself to his boldest deed: crossing the channel from England to France. A balloon, filled with hydrogen gas, which had already made five ascents without any accident, bore the car, in which, together with Blanchard, an American, Dr. Jeffries, was seated. In the presence of an immense multitude the two heroes of the air rose, Jan. 7, 1785, at Dover, and mounted, borne by the wind, several steeples high over the tossing sea. But they soon found cause to rue their boldness. The gas escaped so rapidly that the balloon threatened to fall into the water. The aeronauts threw out their 30 lbs. of ballast, and then all the articles they had taken with them, and even a part of their clothes, into the ocean roaring beneath them. They would have been lost, however, if the wind had not borne them just at the right moment toward the French coast, in the vicinity of which the balloon again rose and floated on without injury into the forest of Guienne, a league from Calais. A monument erected there in honor of Blanchard, was designed

to preserve the memory of his exploit, the success of which the king of France rewarded with a present of 12000 francs, and with the assurance of an annuity of 1200 francs.

This ignorant adventurer, who was destitute of all knowledge, scientific or mathematical, who in his extravagant self-estimation announced himself everywhere as "aeronaut of both hemispheres, citizen of the principal cities of both worlds, member of foreign academies," thus succeeded without consideration or due foresight in an enterprise, which was shortly afterwards undertaken at the cost of his life by an excellent man, thoroughly instructed, who ventured not upon the attempt until after all care had been taken, and all the helps secured, which science could afford. Blanchard's history shows us how fortune can raise a man, even when understanding is wanting. It shows us that the admiration of a crowd of cotemporaries furnishes no standard of real merit. With all his fortunate excursions into the upper sky, of which at his death, in 1809, he numbered 66, he rendered no essential service to science or to posterity, although some have wished to ascribe to him the invention of the parachute which properly belongs to Stephen Mongolfier,—that parachute, by means of which he let himself down several times from considerable heights, for the amusement of spectators, in different countries of Europe and America, and a knowledge of which was of no use to his wife, who carried on his trade after his death, when in July, 1819, she ascended at Paris, in order on a beautiful summer night to delight the crowd with a discharge of fire-works from the balloon, by which the balloon caught fire and the poor heroine fell to the earth and perished.

While Blanchard's name and achievements everywhere excited the greatest admiration, and appeared to cast in the shade all similar enterprises, the scientific and enlightened authors and promoters of the new art were silently engaged in endea-

voring to perfect it and render it more secure. The chemist *Rozier* had gone to Lyons to the elder Mongolfier, and, in company with him, had prepared a balloon of more than 12,000 cubic feet contents. In an ascent made with this balloon, and in which Rozier was accompanied with 7 other persons, it was proved that the danger increased with the size of the balloon, for the gigantic ball, when it had risen to a height of 3000 feet, suffered, after 15 minutes, a rent. It fortunately descended, however, without injury, to the earth. All the attempts of Mongolfier and of MM. *Alban* and *Vallet*, to regulate the horizontal motion of the balloon by means of a rudder, proved fruitless; and their repetition by others has had no successful result. On the other hand, Rozier, and after him, several others, especially Count *Zambeccari*, succeeded by a very simple method, in regulating the rising and descending of the mongolfiere. A spirit lamp was connected with the balloon, and, by the opening and closing of certain valves, the lamp could be kindled or extinguished. The heating, and consequent expansion of the air in the balloon could be increased or diminished by a slight increase or diminution of the flame of the lamp, so that in a few seconds the balloon could be driven to a greater height, or be made to descend in a few minutes to the ground. Although, however, the greatest possible care was taken in adjusting such a circular, ring-formed lamp to the mouth of the mongolfiere below, yet this arrangement was attended with great danger, as the spirits were liable to be shaken by the frequent and sudden gusts of wind to which the balloon was exposed, and thus the balloon itself might be set on fire. An accident of this sort probably led to the unfortunate result of the second attempt to cross the British Channel, made by the French aeronauts. This second attempt to pass through the air over the sea promised a result at least as favorable as that of the former attempt by Blanchard, for the person who

undertook it was a thorough chemist, the season most favorable, and all the preparations for the voyage were made with the greatest care. In order by means of his lamp apparatus to regulate his ascent or descent, Rozier provided himself with a mongolfiere in addition to, and placed below, the balloon which was filled with hydrogen. Like Blanchard, Rozier took a companion with him: the parliamentary advocate *Romain*, from Boulogne. Blanchard had passed from England to France. The present excursion was the reverse, starting from Calais for Dover. The 14th of June was appointed for the ascent. Soon after 7 A. M., the balloon rose majestically with the two men of science; the south east wind, into whose current they passed at some height, appeared to bear them straight towards their goal. But soon the wind set in east, and this change was followed by one still more unfavorable; a current of air carried the balloon from the sea back again towards the French coast. The two gallant men were at least to find their graves on their native soil, and not in the waves. The inflammable air of the upper balloon in the dangerous vicinity of the montgolfiere probably took fire; the whole machine fell from a great height with indescribable rapidity and violence to the earth, and the fragments lay scattered on the ground a league and a half from Boulogne, only a few hundred steps from the sea; the bodies of the aeronauts were so mangled, that the human form was hardly to be recognised. Their remains were buried at Vimile. Thus perished a man, for whom one would have wished a better fate, because, among all, he was the first to intrust his own person to an air-ship, and to rise with it into the uncertain element, and because he had done so much for the advancement of that art, to which his life was sacrificed.

This was the first instance in which the newly invented art had had so frightful a result. For, with the exception of the French painter, Bouche, who, however, when his balloon at

Aranjuez took fire, had saved himself by a leap, there had taken place up to that time (1785) 35 ascents by 58 different persons, and no accident had occurred. Among these adventurers was Mad. *Thible*, at Lyons, the first of her sex who trusted herself to a balloon, and who achieved the excursion June 4, 1784. The charm of the novel and beautiful art was so powerful, and so heightened by the continued success of Blanchard and others, that the fate of Rozier and Romain could not prevent these aerial excursions from becoming more frequent and general. Among the most interesting adventures of this kind is that of *Crosbie* especially, who ascended at Dublin, with the design of crossing the channel between Ireland and England. His car was adapted equally to the air and to the water, and to this construction he owed his rescue from destruction. For the wind, at first favorable, and promising to bear him straight to England, changed to the north-east; the bold man soon found himself 40 English miles from the Irish coast, at a heighth, from which he could see indeed both England and Ireland, but where the pleasure, which this grand prospect would have given him under other circumstances, was very much lessened by the effect of the surrounding air upon his body. For although below, on the earth, the hot July sun shone with full power, at the heighth at which the aeronaut found himself, it was so cold that the ink which he took with him was frozen, and the quicksilver in the thermometer sank into the ball. This, however, was not the greatest calamity of that excursion. Crosbie had let off a portion of the gas, in order to descend into a lower, milder region; when he had reached which, he was borne by a north wind through a cloud, in which he saw lightnings and heard thunder, his air-ship gradually sinking lower and lower, until the waves beat into his car, the balloon driving all the while before the wind, and dragging the car along with it towards the English coast, where

a vessel came to the assistance of the aeronaut, and took him and his balloon safely into port.

An aeronaut, whose bold adventures by air and water excited at the time great interest in several countries of Europe, was the Italian Count *Zambeccari*. In 1783, he had sent up a balloon of considerable size in London, and afterwards had contributed much to advance the new art. When, at a later period—October, 1803, he ascended with two companions at Bologna, the balloon rose to such a height, that the aeronauts were well nigh frozen, and the Count himself afterwards lost three fingers, in consequence of being frost-bitten on this occasion. From this great height, they let the balloon descend, but it came down on the Adriatic sea, where the three men were saved, but the balloon was carried by the wind to the Turkish fortress, Vihacz, where the commandant cut the supposed gift of Heaven into little pieces and distributed them among his friends. Upon a second attempt, in August, 1804, Zambeccari rose again into the region of intense cold, and again descended upon the Adriatic. Nevertheless, his zeal for new trials suffered no abatement until in 1812, at Bologna, he perished in one of his favorite enterprises.

As to any advantages afforded by the art of sailing in the air, or any knowledge obtained by these excursions into the upper regions,—men have not advanced in sixty years much farther than they had got in the first five years after the invention of Mongolfier. No safe means has yet been found of controlling the movements of the balloon at pleasure, like a ship on the water. All that has been obtained is the power of rising or descending at will, and thus of passing from one current of air, unfavorable perhaps, to another and more favorable one. On the whole, the aeronaut is at the mercy of the wind, upon the direction and speed of which, the swiftness of his traveling depends. The greatest horizontal speed, observed in a balloon,

was 17½ German miles per hour. Such was the rate traveled by *Garnerin* in company with Capt. Sowdon, in 1802, from London to Colchester. The great balloon, sent up Dec. 16, 1804, at Paris, fell the next day, after being up 22 hours, not far from Rome, the moderate speed, which it observed in passing this distance of 230 miles, crossing the high Alps, amounted to more than 10 geographical miles in an hour. At about the same rate Robertson's air-ship at Hamburg sailed. A small balloon, sent off June 16, 1804, at Gröningen, fell after 12 hours at Halle, and had run almost five miles in an hour. Seventeen and a half miles an hour gives 110 feet in a second. Ten miles 64 feet in a second; the eagle flies 95 feet in a second.

The rate at which well made balloons rose perpendicularly, was in many cases estimated at 30 and even 50 feet in a second. As the eye of the aeronaut has no stationary object near, by which it can measure the rate of the progress made, but as it seems to him, even when he is going quickest, as if he were standing still, so the ordinary degree of speed can be reckoned only by the time taken to reach a certain terminating point of his course, which can be ascertained in ascending only by observing the barometer. When the way upward leads through the clouds, the clouds do not appear as to us below as fixed masses, but as ragged, torn textures, hanging downwards, and falling down, as the balloon ascends. The highest point, ascertained with scientific accuracy by the barometer, to which an aeronaut has risen, is that which the celebrated French man of science, *Guy Lussac*, reached in his ascent, Sept. 16, 1804. It amounted to nearly 22,000 feet, exceeding the height of the summit of Chimboraso 2,000 feet. The observations made in regard to the gradual decrease of the density of the air, and of the law of this decrease, are in general the same which have been made upon very high mountains, of which we shall speak

in the sequel. At present, some less general phenomena are to be noted, which many aeronauts have observed, when they have reached great heights.

Birds, accustomed to live only in the lower regions of the air, in the neighborhood of the earth's surface, show themselves very susceptible of the influence of the cold, rarefied air of the higher regions of the atmosphere. When taken up and set free at a great heighth, they manifest great distress, clinging with their feet to the cords or the rim of the car, or if thrown off, they fall, as if disabled, and probably continue falling, until they reach, in a lower region, that degree of density in the atmosphere in which they are accustomed to live and fly. The conversion of water into vapor or the boiling of water depends, not merely on the degree of heat to which it is subjected, but also on the pressure of the atmosphere. The farther we descend, so much the greater is this pressure, and so much the greater must be the heat employed in order to make water boil; the higher one rises over the surface of sea and land, so much the less is the pressure of the superincumbent column of air, and so much less heat is needed to convert water into vapor, or, in in other words, to make it boil. Upon the summit of Dhavalagiri, water would boil, and in boiling possess comparatively so low a degree of heat, that an egg could scarcely be boiled hard in it.

The vapor, which, especially from violent motion, escapes from the surface of the human body as perspiration, and shows itself in part in a fluid state as sweat, is occasioned by the internal warmth of the body, in a way akin to that in which the vapor rises from water, when water is made to boil. Although below, in the neighborhood of the earth's surface, the pressure of the air upon the body is much less than at a great height, yet in the thin cold atmosphere of mountain-tops, we fall into a profuse perspiration upon slight exertion, even when the internal

warmth is so little increased, that below on the plains, scarcely a change in the usual state of the skin would be observed. *Biot* and Gay Lussac felt little of this annoyance, because, reclining quietly in their car, they scarcely moved, except perhaps a finger or a hand. Nevertheless, a certain feeling of oppression, connected with a shortness of breath and an acceleration of the pulse, is a necessary consequence of the rarefied state of the air; because the lungs, in the act of inhalation, take in indeed the same quantity of oxygen gas or vital air, in respect of bulk, but the amount of the same in regard to weight is less than suffices to support life in its vigor. At the same time also, in the proportionate degree, in which the external pressure is diminished, the expansion of the internal fluids is increased, so that there arises towards the surface of the body a swelling and a strong determination of the blood, which breaks out, like perspiration from the delicate skin of the eyelids, the nose and the mouth. Aeronauts, who have ascended to great heights, have been found upon their return to be swollen and discolored in their faces. Some have complained of being attacked with deafness attended with pain; when in the higher regions of the air, they have suffered a painful feeling in the drum of the ear, as if it would break through an internal pressure, and while the sound of a loud voice, or the report of a pistol, or of fulminating powder, is much more faintly perceptible in a very rarefied air, the auditory nerves were much more strongly attacked than in lower regions. Even the impressions, received by the eye at very considerable heights, are, in part, different from what one might perhaps expect. It is true, the aeronaut may easily and rapidly rise, if his balloon is well constructed, beyond the region of the thicker clouds, which are seldom more than 14,000 feet above the earth, (although Gay Lussac saw clouds at a height over one and a half times as high,) and although the people of the country below the aeronaut, have a cloudy sky,

or rain, he may enjoy perhaps unobstructed the light of the sun and the stars, but yet, at those great heighths, the full clearness of the atmosphere is obscured as if by a fine streaky cloud, and when it is not so, the stars are seen with a brightness painful to the eye as upon a blueish black ground. The appearance of the earth lying far below is, here and there, even in clear weather, dimmed as by a glassy veil.

The excursion, which shortly after the invention of the balloon, was made by the Mongolfiers over a space of 50 leagues, from Paris to Beuvry, in two hours time, and many other similar ones, have been cast into the shade in more recent times by the ascent of the aeronaut *Green*, who ascended in London and remained 48 hours in the air, passing over the sea and then over Holland and Belgium, until he reached Nassau, where he descended. An attempt to apply aeronautics to public purposes was made in the wars of the French Republic. Balloons went up, in which intelligent observers were seated, who were to reconnoitre the position of the hostile army. Thus, in 1795, on the day of the battle of Fleures, French officers ascended as high as an ordinary steeple, in order to examine the encampment of the Austrian army. The balloon used on this occasion was the same with which Robertson afterwards made an ascent at Hamburg. It was 57 feet in circumference, and of an elliptical form. The force with which the strong wintry current of air strove to tear it from its position, was so great that from 30 to 40 horses were harnessed to it by means of a line, let down to the earth to hold it fast. The scouts, hovering in the air, wrote their observations on tickets, which, loaded with lead, were transmitted by a cord to the earth. In the course of the war about 34 balloons were employed on this service. Against one of them a battery of 17 pieces was opened at Maubege, June 13th, but without effect. The use of balloons for such purposes was, however, relinquished, proba-

bly on account of the length of time required to fill them with inflammable air. For although, within the first ten years after the invention of the art of sailing in the air, such improvements were made, that, from iron filings and diluted sulphuric acid, a sufficient quantity of gas to fill a tolerably sized balloon could be obtained in a few hours, a matter which previously took whole days, it yet appeared that, in the rapid changes in the course of a battle, the space of several hours proved to be an hour too long.

The difficulty, just mentioned, the English aeronaut, Green, learned to obviate by filling his balloon was gas obtained from coal, which is procured easily, and in great abundance, and is used for gas-lighting. The so-called coal-gas is indeed somewhat (almost in the proportion of $1\frac{1}{2}$ to 1,) heavier than the hydrogen obtained from iron filings, but it has the advantage that it escapes through the sides of the balloon with much greater difficulty, and is very much cheaper, and more speedily procured. In the cities of England, where gas-lighting is used on the largest scale, there are always considerable supplies of gas, which Green was enabled to obtain at once.

To remove another and still greater obstacle in the way of aerial navigation, which lies in the choice of materials for the manufacture of the balloon, several things have been lately proposed which appear adapted to that end. As boats have been made out of thin metallic plates, of iron, for example, it has been suggested that balloons might be made of thin copper plates, which, of proper size, might hold such a quantity of inflammable gas, that the comparatively greater levity of the gas would suffice to elevate into the air both the weight of the balloon and the car with its contents attached to the balloon. From such a balloon the gas could not escape, but it is doubtful whether thin metallic plates, like the much more yielding material of which balloons have hitherto been

made, would sustain the changes in the pressure of the air at different heights of the atmosphere, without becoming bent or perhaps rent. However, we may not doubt, that human sagacity will find means to overcome all the obstacles, which up to the present day, obstruct the completeness and general utility of air-ships.

26. VITAL AIR AND NITROGEN GAS.

Among simple substances, the most influential, and therefore the most important, is *Oxygen*. By itself alone, in its pure state, it never appears otherwise than in the form of air, and in this form it is diffused, as *oxygen gas* or *vital air*, throughout the atmosphere. With much greater right than to gold, would the chemico-astrological sign of the sun belong to vital air; for what the sun is among the bodies of the solar system, oxygen is in relation to all the substances of this planetary world. It is the attractive power of the sun which keeps the planets and comets in their orbits, which irradiates over all light and heat; in like manner it is oxygen that gives to the material world its internal order and its firm outlines, and that, everywhere, where it enters into powerful combination with its inflammable opposite, like an earthly sun, diffuses light and warmth.

The moving and upholding influence, as well as the warming and enlightening power of the sun, acts from a great distance. Oxygen requires for its activity to be at hand, and in reciprocal combination with other substances. As the nerve-fluid, (*nerven-äther*,) which is the means of all motion and sensation, and even of the determinate shaping of the *living* body, but cannot thereby itself become a forming and fashioning substance, is related to the blood, in which, together with the life supporting

principle, all the substances necessary to the forming of the several parts are found, so the planetary (sidereal) influence of the sun upon terrestrial things is related to that influence, which is exercised by oxygen in the world of matter.

All the parts of the body seek union with the blood, seek to take it into their composition; and that, which gives to this demand for the blood, its power and its permanence, is particularly the oxygen which exists in the pulsating veins or arteries. Just so is there in the elements of the material world a more or less greater demand for combination with oxygen gas, which presents itself to them partly as a main constituent of water, and partly as an actual ingredient of atmospheric air.

Oxygen gas is most easily and purely obtained from those bodies which are formed by the combination of oxygen with metals—from oxydes; particularly by heating manganese ore, which contains oxygen in a comparatively much greater quantity than other metallic oxydes. Also from the red oxyde of mercury oxygen is obtained by heat. The fresh leaves of plants, when the sun shines on them, exhale vital air.* But near at hand as the discovery appeared to lie, it was not until 1774, that two chemists, *Scheele* and *Priestley*, the one in England, and the other in Sweden, in fact at the same time, obtained pure oxygen gas, and noted its peculiar characteristics.

Pure oxygen is without odor or taste. While, among all transparent bodies known to us, hydrogen gas refracts the light the most powerfully (turns its rays from their straight direction,) oxygen possesses the weakest and least power of refraction. Of its specific gravity we have spoken, (p. 205). Oxygen shows itself as the generator and giver of flame in the most striking manner, when it is pure and when an inflammable body is set on fire in it. Phosphorus burns in pure oxygen

* Most easily obtained from the chlorate of potassa by heating it.

gas with a flame, which, in strength and brightness, resembles the light of the sun; a lighted coal or lighted spunk, in oxygen, give forth a clear flame, and even a steel watch-spring, or an iron needle begins to burn, when a light coal or piece of spunk is fastened to one end of the needle and then inserted into pure oxygen gas. In this case the iron, gradually burning off, melts to a ball from which bright sparks are emitted in a star-like fashion, attended with a loud, hissing noise. The ball of melted iron when it has acquired a certain gravity, falls off, and its heat is so great that it remains red hot for a long time even in water, and melts itself deeply into the bottom of a vessel of glass or porcelain, and even burns a hole through it, if it is not protected by a layer of sand. Pure oxygen is wholly consumed in the combustion of a proportional quantity of phosphorus, while this combustible body, if set on fire in a closed vessel filled with atmospheric air, takes up about a fifth part of the same, and leaves the remaining four parts free, because they are not oxygen but nitrogen.

When phosphorus is burnt in this manner, an acid is produced which, in a dry state, appears in delicate white flakes, and greedily attracts water with a hissing noise. Mixed with water it has a strong, but not disagreeable taste, its weight is exactly that of the phosphorus and the oxygen consumed in the process. In the same way, the combustion of sulphur produces sulphurous acid, the combustion of carbon, carbonic acid, which, when present in sufficient quantities, communicates to many of our medicinal springs their agreeable acid taste. In the fermentation of the sap of many plants, a kind of slow combustion, a combining of carbon with oxygen gas, takes place, in which a portion of the hydrogen escapes. As the sweet taste of the juice of grapes is thus turned into the sourish taste of wine, and, by a still higher degree of fermentation, into the complete acid of vinegar, oxygen gas shows it-

self here also, as in the simple combustion of carbon, to be the efficient cause of acidity, and this is the reason why to this important kind of air, the Germans have given the name of *Sourstuff gas*, (*Sauerstoffgas*). The word *oxygen*, of Greek derivation, is expressive of the same quality.

But under the name also of vital air, it is known by another of its essential properties. When a small warm-blooded animal is confined under a bell-glass, filled with atmospheric air, it must after a while be suffocated, when it has, as far as possible, consumed, in breathing, the oxygen contained in the glass. When the same vessel is filled with pure oxygen instead of atmospheric air, then the animal will live four times as long therein. Only so long as it is surrounded by oxygen gas in a state, chemically unmixed, does a light continue to burn, or an animal to breathe. For that which takes place in the breathing of an animal, with the consequences which follow, may be considered as a process of combustion, by which the internal heat of the living body is brought out, and with it, like the light, various other forces, all subserving the activity and continuance of life.

Thus is it oxygen gas, that, among all the elements of matter, appears to be the most necessary to the support of the external economy of man's condition and to his internal corporeal being. Without this king and sovereign in the domain of simple substances, we should have no light to illuminate our nights, or the darkness of the depths, no fire to protect us from the frost of winter, or from the cold on mountain heights, no means of cooking our food. By means of the flame caused by oxygen gas, man possesses power to melt and work the metals, and may dwell, in domestic comfort, in the neighborhood of the continual ice of the polar regions and the snow-crowned Alps. Only by the help of the fire, which vital air affords, is man master of the external world; without its con-

stant and generous offices the living soul and central life of him would soon lose the power to move the body and to use it as its property.

How, by means of the mutual agency of oxygen and the other elements in the domain of inanimate nature, those motions and activities are generated, which are similar and akin to the activities of the vital principle, and which are comprehended under the name of electro-chemical forces, we shall speak hereafter. That the mountain-masses, of which, the surface of the earth is composed,—that most of the ores and various kinds of stone, which exist in the beds of those masses, consist chiefly of a metallic base, which, by its combination with oxygen, first receives its present enduring consistence and its definite form, we have mentioned above. (ch. 18).

Down into the greatest depths known to us, up to the greatest heights of our planet, the empire of oxygen gas extends. There, as a component part of water and of solid bodies, it has settled itself down to rest as in a more abiding dwelling-place; here, in the atmosphere, it exists in a state of freedom and unrestricted activity. Although it should be supposed, that all the oxygen gas, which is daily consumed by the multitude of flaming volcanoes and by the fires kindled by men, by the countless breathing lungs of living animals, and by all the processes of oxydation and of other slower forms of combustion, is never again separated, and returned to the atmosphere, the circumambient air of the globe may, nevertheless, be considered as an inexhaustible store-house of *vital* air. According to a calculation of science, the amount of oxygen in our atmosphere is so great, that all the above mentioned processes, whereby a portion of it is consumed, would scarcely occasion any perceptible diminution of it in many thousands of years. For although a healthy, grown up man daily consumes in breathing something over 26 cubic feet, and in the course of a year

9505 cubic feet, and consequently the whole collected race of man on earth, taking their number at 1000 millions, consumes yearly $\frac{4}{5}$ of a cubic mile, yet, if such a number of men were to be breathing on the earth for ten thousand of years, only the thousandth part of the atmospheric supply of vital air would be used up. But not only this, but a vastly greater consumption of this life-element, may be supplied in the way already mentioned, by the green vegetable kingdom, whose woods and fields cover so considerable a part of the earth's surface, every ray of sun-light calling forth from this living green an incalculable quantity of the purest vital air.

Next to carbon, oxygen, according to its weight, forms the most considerable substance of organic bodies. Even in the human body, leaving out of view the oxygen contained in the water, which amounts to three quarters of the collected weight of the body, the amount of oxygen in the solid parts is 7 lbs., an amount which is exceeded only by the weight of carbon, (10 lbs.)

We have now considered three of those elements, of which the material for the wondrous structure of the bodies of plants, animals, and even of man, is prepared. A fourth yet remains to be considered, which exists very rarely among the component parts of vegetable bodies, but all the more generally among those of the animal body, viz: nitrogen, which, by itself alone, in a pure state, never appears otherwise than in the form of air,—as nitrogen gas.

When phosphorus is burned under a bell-glass, filled above with atmospheric air and placed over water, and no more phosphorus and no less than is necessary is used, (about 1 grain to 12 or 13 cubic inches of water) the oxygen, which is in the air, is entirely consumed, the phosphoric acid thus produced dissolves in the water, and the yet remaining atmospheric gas, if not alloyed perhaps by a small admixture of vaporiform

phosphorus, is nothing but nitrogen. A lighted spirit lamp allowed to float on the water in the lower part of the bell-glass, goes out only when the oxygen of the air is almost entirely consumed, and when the carbonic acid gas, formed by the burning of the spirits of wine, is got rid of from the portion of the air remaining unconsumed, by mixing caustic ammonia with the water in the glass, there remains only nitrogen, in a state almost entirely pure.

Nitrogen is separated from atmospheric air in a yet purer form than by either of the above mentioned methods, when an amalgam of lead and mercury is placed in a well closed vessel, $\frac{1}{3}$d of the metallic mixture with $\frac{2}{3}$ds of common air, and is shaken up for several hours, the lead, in fine particles, attracts the oxygen and becomes oxydised, and what remains is pure nitrogen.

When the water, that, in the first two methods just mentioned, fills the lower part of the glass, stands in connection with a tub of water, so that the water can pass under the glass, it is observable that, during the combustion of the phosphorus or alcohol, the water rises higher in the glass cylinder, because, by the diminution of the oxygen, a vacuum is produced to the extent of a fifth of the whole volume. For the nitrogen is almost a seventh part lighter than the oxygen, so that, according to the space which these gases occupy in the atmosphere, the oxygen forms only 21, the nitrogen 79; according to weight, the oxygen forms 23, the nitrogen 77 hundredths of the atmosphere. This proportion is throughout uniform. As high as man has risen, as low as he has descended into the depths, to which the air has access, chemical examination has always shown that, apart from those foreign gases, which are found and which displace in a degree the peculiar atmospheric gases, with 21 parts in volume or 23 parts in weight of oxygen, there exist 79 parts in volume, or 77 parts in weight of nitrogen.

Indeed the rarity of the air at very great heights, or its density at very great depths, may be such, that the air in a bell-glass, which may be sufficient on a plain to consume a certain quantity of phosphorus, and to convert it into phosphoric acid, at a greater height may not suffice, and that a part of the combustible remains unconsumed, although the oxygen, which was in the air, is entirely taken up. For, although in the air which exists in the higher regions, the two atmospheric gases, in regard to weight, are both present in the same proportion as below, on the plain, both gases are expanded into a much larger volume, so that a vessel of a cubic foot in measure can contain in weight only two-thirds or even half so much air as below, upon the surface of the sea, or at the sea coast, (ch. 28.)

The two just named chief gases of the atmosphere are united therein, not in the way of chemical combination, like oxygen and carbon in carbonic acid gas, or hydrogen and oxygen in water; neither can the mixture of these two gases in the air be considered as a mechanical union, because if so, the oxygen gas, on account of its greater specific gravity, would sink and fill the lower regions of the atmosphere, and there predominate, while the nitrogen would prevail in the higher spaces. The two must be united, therefore, part for part by a polaric attraction of a different sort, resembling magnetic or electrical more than chemical attraction. That attraction also, which the waters of the earth manifest towards the air, by which their depths are penetrated by air, must be of a similar kind, for the water takes in the gases of the atmosphere, not in the relation in which they present themselves to its surface, but with a sort of selection or choice, absorbing a third more of oxygen than nitrogen.

The relation in which the nitrogen, predominating as it does in quantity, in our atmosphere, stands to the oxygen which it envelopes, appears everywhere as a beneficent relation, neces-

sary to the support of things as they are. If the atmosphere consisted only of oxygen, every flame lighted on our hearths would become an inextinguishable conflagration, and the course of animal life would be deranged. Animals, allowed to breathe oxygen gas for a length of time, appear at their ease at first, but soon become distressed, and their lungs are affected with a kind of inflammation; the collected mass of the blood becomes unusually red. Persons with weak lungs suffer pain almost immediately upon inhaling pure oxygen gas.

We are chiefly considering here, however, only the properties of nitrogen and some of its combinations. Towards oxygen, nitrogen stands in the relation of a combustible body, which fortunately indeed does not enter into combination with oxygen so readily as most other combustible substances. For while good, refreshing water is formed in the combustion of hydrogen with oxygen, from the chemical union of nitrogen with oxygen there arise combinations which are hurtful and dangerous to animal life.

One of our strongest acids, *nitric acid*, which, in its somewhat diluted state as an article of commerce, is called aqua-fortis, (strong water) is nothing but a combination of nitrogen with oxygen, consisting of one atom of the former and five atoms of the latter. The destructive power with which this acid acts upon organic bodies, is known. The reddish vapor also, which is generated in the preparation of nitric acid, for example, by means of the distillation of saltpetre with sulphuric acid, is an acid containing less oxygen than nitric acid, and therefore not so strong; nevertheless it acts upon the lungs as a destructive poison. The same is true even of nitric oxyde gas, which is chemically composed of two atoms of oxygen and one atom of nitrogen, for in this gas also lights are extinguished, and animals cease to breathe. Among all the combinations of the two atmospheric gases, the most hurtful, and

on account of some of its properties, the most seductive, is the nitrous oxyde or laughing gas, in the preparation of which one part of oxygen is combined with one part of nitrogen. In this gas, which is obtained in the purest state from nitrate of ammonia, and further, by dissolving iron or zinc in nitric acid, greatly diluted with water, the flame of an inflammable, lighted body, is increased almost in the same degree as in pure oxygen. Even carbon and iron burn in nitrous oxyde gas with a bright flame, yet there is needed to set them on fire a higher degree of heat than in pure vital air. Small animals, confined in a vessel filled with nitrous oxyde gas, manifest for a time great liveliness. Persons who draw this gas into their lungs, previously discharged of air by a strong expiration, become aware of an agreeable and sweetish taste, and fall into a pleasing state of intoxication, which, by a long continued inhaling of the gas, may increase to delirium. These phenomena in human beings, however, are attended by no injurious consequences, while small animals, who breathe this gas, without any intermission, die at last as if from intoxication.

Nitrogen may indeed be combined with oxygen and consumed by means of the electric spark, but only with very great difficulty, and by often repeated electric discharges, because in the process of that combination, only a comparatively slight degree of heat is developed. When atmospheric air is mixed with four times the quantity of damp oxygen gas, and an electric spark is then communicated to it, only that small portion of nitrogen which is struck by the spark is consumed, and more than a hundred discharges of a common electrical machine are required to generate only so much nitric acid as may indicate its presence by the red color of litmus tincture, or by its forming saltpetre by combining with a solution of the caustic alkali, potash, thus forming nitrate of potash. Nevertheless, a portion of nitric acid may be generated in this manner also in

the atmosphere, either in thunder storms, or by imperceptible electric discharges, for not unfrequently a trace of the same is found in rain water.

Only in a somewhat different way from carbon, does nitrogen also set certain limits to human art in the treatment of it. We know that the costliest of the precious stones, the diamond, consists of nothing but pure carbon, and yet we cannot make diamonds from carbon, because, we are as unable by our art to reduce carbon to a crystalline state, as to awaken to life the elements of which the body of an animal consists. In like manner we see nitrogen combining with oxygen by means of the vital power, which dwells in plants and animals, and this too, readily and without ceasing, while we can only with extreme difficulty imitate this process by our science. On this account we can produce on a large scale nitric acid, and all its varieties from the combination of the atmospheric gases, only by availing ourselves of the previous agency of the power of life in organic nature. For in the slow decomposition of vegetable, and still more of animal bodies, there is generated without great trouble, the nitrate of potash or saltpetre, from which nitric acid is obtained by separating the alkali from this stronger acid by means of sulphuric acid. In our saltpetre laboratories, saltpetre is obtained in a very simple way. Under a roof, to keep off the rain, a quantity of loose earth, of ashes and marl, and all kinds of animal and vegetable refuse, is deposited and frequently turned over to bring it into contact with the air, and watered occasionally with urine. In this way, in the course of two or three years, the (organic) nitrogen is converted into nitric acid, which becomes saltpetre by combining with the potassa, contained, in part at least, in the decomposed organic mass. But saltpetre is found also in a prepared state in many lime-stone quarries and strata of the earth in hot countries, which are covered with a luxuriant vegetation and thickly

populated with animated life. Some plants, as the *Borago officinalis*, contain saltpetre in perceptible quantities in their sap.

In the decay and decomposition of organised bodies, nitrogen enters also into a combination with the other element of water, hydrogen, three parts of hydrogen with one part of nitrogen forming the volatile alkali, or ammonia,* which manifests its presence by its sharp stinging smell, wherever animal matter, of a kind containing nitrogen, is undergoing decomposition. In this combination, a quality is found to belong to nitrogen, which we observe in no other inflammable body. While the combinations of phosphorus and sulphur, for example, with hydrogen, form acids, the union of nitrogen with the same presents a perfect alkali, which, by the addition of a yet further portion of hydrogen gas by means of electrical polarisation, becomes a metallic body, amalgamating with mercury, and similar to the bases of other alkalis. We have here all the usual relations reversed. In other cases the metallic base is made apparent by the withdrawal, by means of hydrogen, of the oxygen, by combination with which the metal is oxydised. In this case the hydrogen enters into the combination, and now first a metallic substance is presented. But there continue to be some doubts respecting the nature of the basis of nitrogen, and from many observations it would appear that it consists originally of a combination of a base as yet little known, and oxygen. In every respect, this remarkable atmospheric gas seems to be the point at which the dominion of other and higher forces than those of our laboratories, the powers of life take their beginning. From the domain of the bases which form unorganised bodies, nitrogen is in a manner expelled and excluded. Here is nowhere evinced any disposition to unite with it, and even the

* The solution of this gas known as spirits of hartshorn.

to the natural historian, but also to the inquirer into the history of the formation of the earth's surface, and of the permanency of the relations subsisting between the atmosphere and the external condition of the globe. It is found by the microscope that huge beds of the silicious earths, which make so large a part of the earth, are composed of a heap firmly baked together of innumerable shells, in which infinitely small animals once dwelt, for in these atomlike animalcules, a perfection and delicacy of structure, a beauty and proportionate strength of outward form and defence are apparent, which fill the observer with the deepest wonder. At the period when these silicious beds were formed, living beings must have stirred in every drop of the fluid element.

The attention of the natural historian has been drawn in recent times in yet another way to these minute animals, and to their importance to the economy of material nature. We spoke in the former chapter of the consumption of the oxygen of the atmosphere by animals, by fire, by manifold processes of fermentation and oxydation. There is developed, it is true, from the living vegetable world, by the decomposition of carbonic acid, under the influence of the sun's light, a considerable quantity of oxygen gas, but another, and perhaps not less abundant source of supply is in the animal world itself, and in the department of microscopic animals. We will dwell on this fact for a moment.

Several years ago, a celebrated inquirer, Count Rumford, observed, that from various organised bodies, such as silk, woollen and the like, when exposed in a vessel filled with water to the light of the sun, a quantity of the purest oxygen gas was developed. At the same time the water took a green color, which, as appeared by the microscope, proceeded from a countless multitude of little round shaped animals. In the pans used in salt works is seen a slimy transparent mass forming,

which covers the bottom to the depth of one or two inches, and on the surface of which large air bubbles rise. When the slimy skin-like substance of these bubbles is broken with a stick, there issues forth an air, which, upon full experiment, is ascertained to be oxygen gas, perfectly pure. But when still further the thick sticky fluid, from which the gas proceeds, is examined by the microscope, it is discovered to consist almost entirely of a mass of just such living animalcules as those of the shells of which the hill, *Kieselguhr*, at Franzenbad in Bohemia, and other similar strata of our mountain regions are composed. Even in the white ashes, which remain after exposing the thick fluid mass to the fire, we may distinguish the silicious skeletons of the animalcula of which it is composed. These skeletons show so distinctly the form of the animals to which they belonged, that it appears as if one were still looking at the fresh slime which they fill, but only in a dead, motionless state. Other waters also which contain organic substances are, according to various repeated experiments of a recent date, animated with thick heaps of little red and green animals, visible only through the microscope; and a species of air comes from the water, in which, when it is collected under a glass, a burning shaving gives forth a clear flame as in oxygen gas, and by this and other signs it is proved to be pure, or almost wholly pure, oxygen.

When we consider, in this connection, the extensive pools upon shallow sea coasts, filled with saline particles, mixed with a mass of the organised remains of sea animals, when we remember still further the numberless collections of standing water in swamps and ditches, with which also the remains of animal and vegetable bodies are mingled, it will be easy to see the important office which these animalcules discharge in th material world. They consume without ceasing the substances held in solution, which, if they decayed in the ordinary manner,

would poison the air with the exhalation of their corruption. And although these animalcules cannot entirely remove the evil in swampy regions, yet their services in this respect are by no means inconsiderable. But not only is this work of purification and clearing away, committed to these animated atoms, they perform the much more important office of separating the oxygen in entire purity from the water in which it is contained. Here the weakest and smallest are appointed to supply that which is essential to the life and activity of the strongest. What, to our ordinary view, seems contemptible, upon a more thorough and penetrating inquiry is found worthy of recognition and honor.

We shall hereafter, at the close of the chapter on the lightning rod, come to speak again of the significance of the diminutive in the material world in relation to the great and the large. The great, according to its weight and ruling influence, always remains great, but that which strikes our eye in the great and appears of weight,—that would not exist, if there were not around, below and above it another world of things which our eyes see not.

28. PRESSURE AND COUNTER-PRESSURE.

We have now taken a general view of the so-called simple substances, or the elements, which human art has not yet been able to decompose, and out of which material bodies are formed. In unorganised nature these elements are directly applied, like rough-hewn building-stones, to the formation of rocks, water, and other bodies in which no animating life or soul dwells; the vital principle of plants and animals, on the other hand, makes uses of these same substances, as the material, by working and mixing which, like the architect with his mortar and bricks and

stucco, it obtains the perfect organised substance for the vegetable or animal structure.

As the building stones, lying unused on the ground, or the heaps of earth and sand, not yet baked into bricks, attract but little notice, as on the other hand, every passer-by willingly pauses and looks on with interest when whole troops of laborers are putting the dead materials in motion, and gradually a graceful edifice is rising under the hand, so it is when we pass from the less attractive consideration of simple substances to those processes by which the grand fabric of our globe is constructed and arranged. The builders who show themselves busy on this edifice, are partly the forces of an electrical and chemical attraction, and partly the forces of a living principle or soul; the means which both call to their aid, as the mason and the carpenter their tools, are partly of a mechanical kind, depending upon pressure and counter-pressure, and partly of a molecular nature, grounded on polarisation. We will consider first those means which appear to belong rather to the mechanical class, although in their agency is manifested also the self-active energy of peculiar powers. First of all comes that influence which the pressure of the atmosphere exercises on the organization and persistence of the material world.

When a child is asked: Which weighs heavier, a pound of lead or a pound of air, in most cases the answer is: The pound of lead. The child does not consider that a cwt. is a cwt., that an ounce is always an ounce in the scales, whether we be speaking of water, air or gold. The horses harnessed to a car containing a keg full of ducats have to exert as much strength in drawing it as two other horses, whose load is a barrel in which 19 kegs of water are contained And yet the child, in giving that apparently wrong answer, is not altogether wrong; he should only express himself otherwise, and say perhaps: a pound of lead is harder to carry than a pound of air.

The porter who carries 400 lbs. of lead on his back, must be a very strong man, such a one perhaps as we may find among the Turkish porters in Constantinople. A man celebrated for his strength in ancient times, who vaingloriously styled himself Athamas the invincible, went beyond this; he bore on his person a suit of armor which weighed a thousand pounds, and moved in and with this burthen. But we have examples close at hand of much stouter porters, and I myself know one, who carries a weight, almost thirty times heavier than that of Athamas, and with so much ease, that he never once lays it off at night, and by day wanders about with it over mountain and valley. Aye, and this porter, when a little boy, ran and leaped with a weight many times greater than that which Athamas bore on his body, clambering up on trees and walls, and swimming without sinking in the water.

The individual, of whom all this can be said without exaggeration, is not only myself, but every one of us. Every man of full growth and well formed limbs has to bear by day and by night a pressure of the air acting upon the whole surface of his body, which corresponds to a weight of 15 lbs. upon every square inch, accordingly 2,160 lbs. upon every square foot, and upon the whole body, if the whole surface thereof amounts to from 10 to 11 square feet, to a weight of as many tons.

That in a tube, in which a tight fitting piston is drawn up, the water, into which the lower end of the tube is plunged, will ascend, was known from the earliest times to every child, for squirts and syringes are not playthings of yesterday's invention. Every water-pump, which is the same thing on a large scale that a squirt is on a small one, every siphon, in which, when the air is drawn out of it by the mouth, the fluid, in which it is inserted, rises, teaches precisely the same thing, namely, that water and every other fluid, when it can find admission into a space emptied of air, immediately rushes into

it. The fact was long and well known, but not the cause of it. A celebrated philosopher of antiquity, Aristotle, gave out the opinion, that nature abhors a vacuum, for which reason, water, contrary to its gravity, ascends into tubes devoid of air. In this strange dogma, because it came from a great scholar, the world quietly rested for almost two thousand years, without considering the matter any further.

As, however, a vacuum always remains the same, and of course must produce the same effects, whether it be great or small, as, on the other hand, the abhorrence of Nature for a vacuum, should be expressed only the more strongly, the greater the vacuum is, it is remarkable that the water in a suction pump, however perfectly the pump is made, never rises in the artificially generated vacuum higher than 34 feet. A gardener in Florence became acquainted with this fact in a remarkable way. He caused a pump to be made, with due skill, 40 palms high. The water followed the air-tight piston, when it was drawn up to the height of 18 ells, or 34 English feet, but at this height it remained standing, without rising any higher into the vacuum. The celebrated Galileo, one of the most keen-sighted philosophers of modern times, heard of this fact, but, although his independent mind had in many respects released itself from the authority of Aristotle, he was not able to shake it off on this occasion; he judged, that the abhorrence of a vacuum, which made the water rise in the pump, had certain limits. And yet to no one could the correct view of this phenomenon lie so near as to the keen and searching mind of Galileo, who was not only acquainted with the weight of the air which he estimated, although still too highly, at 400 times less than the weight of water, but who also appears to have considered the effects of the pressure of the air upon the surface of the earth. In the present case, the truth was seen by him as from the great distance to which the aeronaut rises; he

lacked the distinct observation of a nearer stand-point, for the difficulty of producing a perfect vacuum in a tube 34 feet in length was too great. But his pupil and successor in the chair of physics at Bologna, *Torricelli*, succeeded in finding that nearer stand-point from which the phenomenon of the pressure of the air could be easily and conveniently observed, because it was limited with its effects, to a small space, and was made to appear with but little trouble. If, so reasoned Torricelli, it is the pressure of the air, which, acting upon the surface of the water, in which the lower end of the pump is inserted, drives the fluid into the vacuum, then must this pressure act upon every point of the earth's surface upon fluids and solids with equal force. The height to which a fluid rises into a vacuum, by means of the pressure of the air, will, so he concluded further, be in proportion to its specific gravity. Spirits of wine, or oil, will rise higher than water, because they are lighter, mercury, because it is much heavier than water, will, in the same proportion, rise not so high. At this step in his reasoning Torricelli paused. He filled with quicksilver a glass tube which was melted together and closed at one end, put his finger over the open end, and then placed it, the open end downwards, in a vessel filled to the depth of 2 inches with quicksilver. Removing his finger, he found that the quicksilver stood in the tube, at about the height of 29.5 inches in the tube, leaving the space between this height and the closed end, a vacuum. But the height of 29.5 inches is to the height of 32 feet in inverse proportion of the gravity of water to that of mercury, namely, almost as 1 to 14. In the glass tube, with its vacuum at the upper end caused by the position in which the tube was placed, the same fact was shown that occurred in the gardener's pump, 40 palms high at Florence. In the pump there had been a vacuum proportionally as large, and yet the water had not been able to rise above a certain height; so like-

wise the quicksilver, in the vacuum of the Torricellian tube, or as we now call the instrument, the barometer and weather glass, remained standing at a certain height. This great discovery, so important in its consequences, was made in 1643.

The truth, when published, as so often happens, was doubted by many. Two of the deepest thinkers of the time, *Des Cartes* and *Pascal*, deemed it worthy of further examination. If it is really the weight of the superincumbent column of air, which raises the water and the quicksilver into the vacuum, then the higher man ascends above the surface of the lowest plains or the level of the sea, the more must that weight diminish. The quicksilver in the Torricellian vacuum, on the top of a high mountain, will not rise so high as below by the sea coast. Thus *Pascal* reasoned, and in 1648, his brother-in-law, *Perrier*, at Clermont, in Auvergne, ascended the Puy de Dome, 4541 feet high with a barometer, in order to observe the height to which the quicksilver rose. Perrier found that on the top of the mountain it stood about 3 inches lower than below at the foot of the mountain. An experiment on a small scale, made by Pascal himself, established the same fact. A barometer, which he took up on the tower of the church of St. Jacques, showed the quicksilver in that position, standing several lines lower than in the street below. Independently of those changes, perceptible in the height of the quicksilver in the barometer, and occurring every day, of which we shall speak hereafter, it became obvious from these experiments that the rising of fluids in a vacuum is uniformly proportional to the height, and of course also to the weight, of the atmosphere, resting on the earth's surface.

What the atmospheric pressure and its effects are, was shown in a way still plainer to the great mass of men, by *Otto von Guericke*, burgomaster at Magdeburg, when in 1654, at the Imperial diet at Regensburg, he performed his experiments with

the air-pump invented by him, in the presence of the Emperor Ferdinand III., his son, the King of Rome, (Ferdinand IV,) several high princes, and a large number of the nobility and throngs of people. As water is pumped up by means of an air-tight piston, so Guericke drew the air from a hollow metallic ball, so fixed that after every draught, the air, which was pumped out, was prevented from entering the ball again by means of a valve; he succeeded in producing almost a perfect vacuum. The vessel which he exhausted of air, whose diameter was an ell (Magdeburg measure,) consisted of two hollow copper hemispheres, which fitted exactly together, and which were made air-tight by a ring of wax and leather soaked in turpentine, placed around them where their edges came together. Metallic rings were fastened to these cups, through which lines could be drawn, and to which horses could be attached. Before the air was exhausted from these half balls, put together and making one ball, they could be separated from each other without any exertion of strength. But when the internal air was, as far as possible, pumped out, the external pressure of the air upon the two hemispheres held them so firmly together, that the united exertions of several strong men could not separate them. To each of the two cups a couple of horses were attached, then 4, and then 6, and the animals were goaded to the utmost exertion of their strength, but were not able to tear the hemispheres apart. Only when 8, and at another experiment with a somewhat larger ball, 12 horses were attached to each half-ball, were the half-balls separated; thus a 16 or 24 horse power was required to effect what the strength of a child could accomplish before the air was exhausted. Experiments were repeated with every variety of form and arrangement of the vessel to be exhausted, and all tended to illustrate the extraordinary force of the pressure of the air, and to show that this pressure acts upon a surface of about a

square foot with the same power as, for example, a heavy metallic mass of the same superficial contents, weighing nearly one ton.

The inventor of the air-pump was led to his invention by the Torricellian vacuum in the glass tube of the barometer. There is no doubt that Torricelli observed the changes which the height of the quicksilver in the barometer underwent, even when the instrument was kept in one place; he had thus ascertained also that the weight, with which the air presses on the surface of the earth, is itself variable. The first, however, who discovered the connection of those changes of the barometer, not only with a changeable state of the atmosphere, but also with changes of the weather, and who turned the barometer into a weather glass, was Otto von Guerike, who describes in a letter, written in 1661, the amusing contrivance of his weather glass, in which a little wooden figure of a man was placed upon the quicksilver, rising and sinking with it, and pointing with his finger to the supposed changes of weather, which were noted alongside of the glass tube.

Thus the barometer serves as a herald of the weather for seamen, when it warns them by the falling of the quicksilver, of the approach of storms, and also for dwellers on the land. But of yet greater importance is this instrument in its application to the admeasurement of heights, because here the service it renders is more decisive. Air is about 10526 times rarer than quicksilver. When, therefore, two barometers are placed, one below on the ground, the other on the roof of a building, which is about 87.7 feet above the ground, it is found that the quicksilver in the barometer on the roof is about one tenth of an inch lower than in the other. For 87.7 English feet are about 10526 tenths of inches; so much the shorter must the column of air be, when its pressure shall so far decrease that it equals a column of quicksilver which is lessened a tenth of an inch. If now, this proportion continued uniformly, so that with

every 87.7 feet in height, the quicksilver sank about a tenth of an inch, the measuring of the elevations of mountains, of places above the level of the sea, would be very simple and easy. But there are other things to be considered. It is not with the strata of air, which we suppose to lie one above another from the surface of the earth up to the highest limits of the atmosphere, as it is with layers of solid bodies. If, for instance, a certain number of stone plates, each two inches thick, and weighing a cwt., are laid one upon another, and one or more of these plates are then taken away, the whole bulk or pile will become, at the withdrawal of every plate, a cwt. lighter and at the same time two inches lower. But the strata of the air of equal weight are not like such solid strata, each unchangeable in its size, and not allowing themselves to be pressed one into another by a weight laid on them, but like the elastic feathers of our beds and pillows, the air, by a pressure acting upon it, may be compressed into a narrower space than it previously occupied, and it expands, in the same measure in which the pressure is relaxed, into a larger space.

The same bulk of air in weight, which below, at the level of the sea, where the barometer ordinarily stands at 30.0 inches, is compressed into a stratum, the thickness of which is about 87.7 feet, will expand to a stratum of double the dimension above at a height where the barometer stands only 15.0 inches, and where, consequently, the weight and the pressure of the upper column of air is become less by one half. There, at that height, which equals the top of Chimborazo, in order to see the barometer again fall about $\frac{1}{10}$th of an inch, one must ascend twice 87.7 i. e. 175.4 feet, and could we rise to a height where the pressure of the superincumbent column of air only equalled the weight of a quicksilver column of perhaps 7.5 inches, then we must rise four times 87.7 or 350.8 feet higher, in order to see the barometer fall $\frac{1}{10}$th of an inch.

In this way then is the height of any point of the earth's surface above the level of the sea measured. At the level of the sea the barometer stands 30 inches high. At a height of 877 feet, the quicksilver stands about a whole inch lower, 29 inches; at a height of 1784 feet, about 2 inches; at 2723 feet, about 3 inches; at 3698 feet, about 4; at 4709 feet, about 5. Thus, as 30 is to 29, or 28 is to 27, &c., in the same proportion is the dimension in height of a single stratum of the air increased, the weight of which is equal to that of a layer of quicksilver of the height of an inch; it has increased from 877 to 907, 940, 974, 1012. When the barometer stands at the height of 22.75 inches, the pressure of the air is lessened about a quarter of its amount at the level of the sea, there also the expansion of the air-column, which according to its weight, corresponds to a column of quicksilver of an inch, amounts to over a 1100 feet.

To give now some examples: thus on the top of Hecla in Iceland, the height of the barometer is 24.70 inches. Calculation shows that this corresponds to the pressure of the air at a height of near 5025 feet, for from inch to inch of the quicksilver level the column of air has expanded from 877 to 907, 940, 974, 1012, then the descent of the barometer from 25 inches to 24.7, corresponding to an ascent of 315.7 feet, these sums added together give 5026. At the monastery of St. Gotthard, in Switzerland, the barometer stands at something over 23.2 inches, hence the height is reckoned at 6822 feet above the sea; upon the summit of the Lomnitz point of the Carpathian mountains, the barometer stands at 21.5 inches, which gives a height of 8720 feet.

On account of the rarity of the air, ever increasing as we rise, it happens that a small balloon, made air-tight and only half filled with air, and of course loose and flaccid, when taken up to a considerable elevation, at once swells out by the elasti-

city of the air enclosed within and expands to such a fulness that it bursts; like a bladder, which, after the air has been expelled from it by the hand, and the neck tied up, is placed under an air-pump. A circumstance which has often periled the lives of aeronauts; for what uncommon strength there is in the elasticity of compressed air is shown by our air-guns in which it is only air greatly condensed, and confined in a hollow ball screwed to the gun, which, when allowed suddenly to escape into the barrel, rushes in with such violence as to send a ball with great force and swiftness.

In air so dense as that at the Dead Sea, the level of which is more than 1200 feet below the Mediterranean, and where accordingly the average height of the barometer is about 30 inches, we suffer no inconvenience, on the contrary, when the barometer is high, we have a sensation of bodily comfort.

Vastly greater are the inconveniences experienced when we remain long in the rarefied air of the higher regions of the atmosphere, apart from the cold, which increases with the height. The unfavorable influence of such rarefied air is shown by the shortness of life, the pale looks, the sickliness, the difficult healing of wounds, observable in the inmates of St. Bernard, at a height of 9018 feet, the average height of the barometer being little over 21¼ inches. Higher up, 7 to 8 miles, an animal would hardly be able to live and breathe. At a height of about 20 miles above the level of the sea, the rarity of the air reaches a degree, which we are unable to produce with our best air-pumps.

In regard to the habitableness of the high regions of the atmosphere, heat has a no inconsiderable influence. There, where (between the tropics) the whole year through, a high degree of heat prevails, the column of air must, through the expanding power of heat, (of which hereafter) be higher than in a colder climate, although the pressure of the air remains

the same. On this account the inhabitants of the high valley of Quito suffer none of the inconveniences experienced by the inmates of St. Bernard, although their place of residence lies upwards of 9000 feet above the sea, the barometer standing below 20 inches. For Quito lies almost under the equator, St. Bernhard more than half way from the equator to the north pole, in 47° north latitude. An answer has been diligently sought to the question: How high is the atmosphere, and what is its utmost limit? According to the law of Mariotte, the space, which any weight of air occupies, increases in the same proportion as the pressure on it diminishes. At the level of the sea, the pressure of the superincumbent air on the lowest stratum is equivalent to a column of mercury 30 inches high, and we have to rise through a stratum of air about 877 feet thick, that the mercury in the barometer may fall one inch, or sink to 29 inches. At the height where the mercury in the barometer is only 15 inches, or the pressure of the air only one half what it is at the level of the sea, we have to rise through twice 877, or 1754 feet in order that the mercury may fall one inch or sink to 14 inches. At the elevation where the barometer stands only one quarter as high, or at 7.5 inches, we have to rise through a stratum four times 877 or 3508 feet thick, that the mercury may fall one inch; and so on. Thus we see that the atmosphere grows continually rarer, or the same weight occupies a continually increasing space, in proportion as we rise higher, and this would seem to go on without limit. But it is probable that the distance to which the atmosphere extends from the surface of the earth is limited, and that the limit of this is to be found where the peculiar elasticity of the air exactly balances its gravity, which, according to calculation, is, under the equator, at a height of 161 miles, (in the neighborhood of the pole, 159 miles above the surface of the

earth.) The air, however, at that height must be so rare that it can reflect no light to the eye; for, as we know by the calculations, which morning and evening twilight enables us to make, the height, at which the air still possesses sufficient material consistency to reflect a dim sunlight upon the darkened surface of the earth, extends to about 45 miles. The density of the air in that region, if its decrease follow the rule of Mariotte, above stated, would be scarcely the 5000th part of the density of the lower strata.

In the pressure, which the whole column of air exerts upon the surface of the globe at the level of the sea, and which is equal to the weight of a column of quicksilver of 30 inches, not only do the two main gases of the atmosphere, nitrogen and oxygen, take part, the first of which corresponds to a column of mercury of more than 23.05 inches, the latter, almost 6.95, but there are two other gaseous substances which are to be considered, and which are found very generally mingled with the air. One is watery vapor, the other carbonic acid, the former composing on an average about fourteen thousandths, the latter a thousandth part of the atmosphere. The pressure of the former, however, is scarcely equal to three-eighths, that of the latter about the fortieth of an inch of the barometer. Yet these proportions nowhere remain so uniform as the proportion of the quantities of oxygen and nitrogen. The carbonic acid gas, especially, on account of its great density and specific gravity, is incapable of rapid and uniform diffusion, but it readily and chiefly collects wherever, by the combustion or fermentation of bodies, it is produced, and even in other regions of the atmosphere; it is remarked that in general the quantity of this gas increases in dry weather and diminishes in wet, and that in still weather and over flat countries and the sea, there is less of it than in windy weather, and

in mountainous regions. The quantity of vapor in the atmosphere is subject to still greater variations, depending much on the temperature, and the situation of the country.

With this variation in the quantity of atmospheric vapor are connected in part those daily and monthly changes observable in the barometer. But these are not the barometrical changes, by which approaching changes of the weather are determined; those changes of the barometer which prognosticate the weather are such as are produced by a disturbance of the equilibrium of the columns of air, resting on different parts of the earth's surface. This equilibrium is disturbed especially by different degrees of heat. The warmer column of air expands and rises to a greater height, and pours itself out over the adjoining lower and colder regions; but the column itself becomes thereby lighter, and its pressure on the earth's surface diminished. Into the warmer and rarer strata of the air, the denser, colder masses of the air sink, according to the law of equilibrium, and thus is produced an upper current of the air of the warmer zones towards the colder, and a lower current from the cold zones to the warmer. The latter comes from a region of the earth, where the velocity of any point on the surface of the earth arising from the rotation of the earth on its axis is less considerable than at the equator; on this account, the more it approaches the regions of the tropics, where the earth's rotation has the highest influence, it is more retarded, so that by reason of the motion of the earth from west to east, it becomes a prevailing current in the opposite direction, or an east wind, generally known by the name of the Trade winds; just as it is with us, when we are seated in a stationary or slowly moving carriage, as soon as it starts or accelerates its motion, we fall backwards.

The air, moving swiftly, exerts a less pressure downwards than when it is in a state of rest, for the same reason that air

driven powerfully through a narrow tube exerts its elasticity less against the sides of the tube than in the direction in which it is impelled. On this account the barometer falls oftenest during and before the prevalence of a strong wind.* The changing currents of air, as a consequence of the different degrees of heat which set them in motion, give occasion to rain which forms in the atmosphere and falls to the earth. Vapor preserves its form only through that elasticity, which heat communicates to it. There may be a great quantity of vapor or steam in the atmosphere, increasing the pressure of the air very sensibly, as the barometer shows us, and yet, at the same time, there may be the greatest draught. But when a mass of warm air, the heat of which is sufficient to give to the vapor with which it is filled to saturation the elasticity necessary to preserve it in the form of vapor, is mingled with a cold stream of air and thereby becomes cooled, then a greater or less quantity of the vapor loses its elasticity and forms little drops which either remain floating in the air and only becloud the heavens, or, when they have attained a more considerable size and gravity, fall to the earth as rain. The cessation of the elasticity of vaporiform water essential to its existence as such is instantly to be perceived by the dampness of the air.

When water, in boiling, passes into a gaseous form, it expands to 1700 times its bulk, and becomes, of course, so much the lighter. Atmospheric air at the boiling point expands only so much as to be 1050 times lighter than water, the vapor of which, of course, still always remains perceptibly lighter, having only $\frac{10}{18}$ths of the weight of the surrounding hot air. But water is converted into vapor, not only at the boiling point, but

* The connexion between the height of the barometer, and the direction of the wind varies in different parts of the world. It has been generally observed at Paris, that the barometer is higher when the wind is from the N. or N. E, than when it sets from the S. or S. W.

also at a degree of cold, far below the freezing point; in the state of ice and snow, water is subjected to evaporation. Vapor, formed at such low temperatures, has not indeed that elasticity which the temperature of the boiling point communicates to it.

Vapor forms rapidly in the vacuum produced by the air pump, and if our earth were deprived of its atmosphere, there would be an envelope of vapor formed around it from the vapor of its waters. The rapidity of the production of vapor by the application of heat to water,—by boiling, is manifestly dependent on the pressure of the atmosphere. While at the level of the sea 80 degrees of heat, according to Reaumur's scale, (212° Fahr.,) are required to make water boil, at the summit of the Puy de Dome, (4841 feet,) a heat of 76 degrees suffices for this purpose, at a height of about 10,000 feet, 72 degrees; and even the good fathers of the Hospice of St. Bernard and St. Gotthard, and the herdsmen of the high Alpine regions, are never able to cook the meat which they prepare for their guests or for themselves, as thoroughly as the inhabitants of low-lying countries, because it is not possible at those heights to give to boiling water the heat necessary to the thorough cooking of many articles of food. In the monastery of St. Bernard, water boils at 73¾ degrees, Reaumur, (173° F.)

To return, however, to the consideration of the influence which the pressure of the air exerts upon the human body, it may be reckoned, that the weight of the atmosphere, under which we, at the level of the sea, live and move, increases or diminishes, with every $\frac{1}{10}$th of an inch that the barometer rises or falls, nearly 70 lbs. At a height of 7462 feet, where water in a pump, instead of rising 34 feet, rises only 25.5, and the average stand of the barometer is only 21½ inches, the atmospheric pressure on the surface of the body is lessened about one quarter of its strength, and where water in a pump rises only 17 feet, at a height of 18,000 feet, the bold mountain-climber,

who reaches that height, has only half the atmospheric weight resting on him that rests on the inhabitant of the sea coast.

Nevertheless, such a diminution of the pressure of the air does not by any means assist, but rather obstruct life and all its movements. Our corporeal being is penetrated with air, and is in a manner, a being of air, on which account it resists the external pressure of the air with its elasticity, by which it maintains an equilibrium to a certain extent. This extent reaches to the point where the air, however rarefied, still possesses that quantity of oxygen, which is necessary, at every breath we draw, to the vitality of the blood. Where breathing takes place with difficulty, the pressure of the external air is diminished to such a degree that the balance can no longer be maintained between the gaseous or fluid and the solid parts of the organised body; the elasticity, or expansive power, of the former is increased to such an excess, that it breaks through the hulls or membranes in which the fluids are contained and finally destroys them. For all organised bodies, on the surface of the earth, composed of solids and fluids, the atmospheric pressure is indispensable to the condition of life and health allotted to them.

Even in the spiritual world there is an analogous arrangement. Every human soul is placed by the Creator in a school which now here, now there imposes external restraints, like the atmospheric pressure upon the elasticity of the physical system. Under this restraining pressure, the mind remains sound and joyous, so long as the peace-giving spirit which ordains the external pressure, lives and reigns within, nay more, the inward elasticity or resisting energy of the mind is strengthened in the same degree in which the outward burthen increases. Were man given over at once to all the motions and cravings of [illegible]nature, without that influence from above which orders and [illegible] all its aspirings, its whole activity would end in [illegible]whole being would sink into nothingness. But not

only above, and without, but within also, in the inner sphere of the mind, there reigns, so long as the inner life is sound, like the airy fluids, which are contained in the structure of the body, that spirit which prevents the ascent of the lower, animal nature, into the higher and more peculiar heritage of the spiritual nature. Where this interior power gives up its authority, then it is with man as with the tube in which, by the rising of the piston, a vacuum is produced, in which the water from the mud and slime of the deep ascends; the animal and the sensual takes the place of the human and the spiritual.

29. HEAT.

We here become acquainted with another assistant of life in the construction of the visible world, vastly more important and more general in its influence than the pressure of the atmosphere, but found continually connected with this pressure and with the activity of the gases which generate it. This powerful agent in the fabrication and maintenance of material things is *Heat*. What would the world be if there were no light with paternal power to awaken life in it, no maternal warmth to preserve and nourish that life! Light and Heat come, it is true, to the earth, from the mighty centre of the system—from the sun; nevertheless, the earth itself contains within its mountain masses, in burning volcanoes, and naphtha-fountains, many natural fire-altars, never extinguished.

At Baku, on the Caspian Sea, where naphtha gushes in different places from the ground, and where, in the neighborhood of these springs, out of every hole dug in the earth a gas rises, which takes fire when a flame is brought near it, and burns steadily on, until it is cut off, perhaps by heaping up the earth over it, from all connection with the oxygen of the atmosphere, there are still found several little communities of the old

Persian fire worshipers. Through a natural error, fire, with its light and heat, appears not only as a symbol of the all-animating, all-upholding power of the Creator, but as the very God himself, before whom they bow in adoration.

Indeed it was an important addition to the dominion of man over external nature, when power was given to him over the heat, which the sun radiates during the day, to produce it by night and use it for his service. When fire was once kindled, it was easily kept by being fed with combustible substances, most easily, and without any effort on man's part, wherever fuel was at hand, as at those naphtha springs or where fire came forth spontaneously over the beds of rock-salt.

We will not ask, who was the first discoverer of fire. Now and at all times one fire is kindled by another; so that it may well be said, that the discovery of fire arose naturally and originally through the force of human intelligence, which comes itself from the source of light, or, in other words, the use of fire in human economy is as old as that economy itself. History, which aims to narrate only the outward visible facts of life, not the interior germinations of the same, tells us the name of the first discoverer or conqueror of fire. A stroke of lightning, so some ancient authors say, set a tree in flames, or a strong wind rubbed the dry trees of a forest so long and so violently against each other, that the wood became heated and caught fire, and the flame, once kindled, was preserved by unsleeping care and vigilance as a sacred thing. Even a transparent crystal, rounded on opposite sides, such as are found among the boulder stones, stones rolled down by mountain streams, may have been used, according to the opinion of others, as a natural burning glass, in order to make the first fire, by the beams of the sun, on the hearth of man.

Some nations, to whom the arts of Europeans are unknown, still obtain fire in the same way in which one of the primeval

emperors of China, according to the legend, taught his people to produce it: by rubbing together pieces of dry wood, by inserting one piece into a cavity made in another piece, and then turning it rapidly round. It must have been obvious,—one of the first facts presented to the primeval inhabitants of the earth,—that every sudden and violent pressure, every collision of solid bodies, every quick motion produces a degree of heat, and oftentimes a degree of light also.

The discovery, which the Chinese emperor made, according to the legend, that a piece of wood, put into a hole in another piece and turned swiftly round, may produce fire, has been made also, to his terror, by many a wagoner when he has not sufficiently greased the axles of his wagon, and the friction has been so great that the heated wood has caught fire. Thus the pins of the wheels of machinery may be heated red hot. The hub of a wheel in going down hill, by the weight and friction which it bears, and an augur, or a saw, after long continued use, may become very hot. The heat, generated by friction, does not depend upon the quality of the substances submitted to this sort of action; plates of metal, of marble, and of wood, by means of an equal pressure, and when rubbed together with equal force, become heated, almost to the same degree. The heat also, which two bodies give out by friction, does not diminish, let the experiment be repeated ever so often and with the shortest intervals. It is thus clear that it is not the bodies themselves, which give out the heat, as a wet spunge by being pressed gives out the water; but it is the external motion which is communicated to the individual parts of the bodies used, even to their inmost substance, that produces therein that peculiar agitation and disorder of the mutual attraction of the minutest parts, which we name Heat.

When a flat-pressed rod of pure tin is bent by the fingers, there is perceived a peculiar sound, the so-called cry of the

tin (*Schreien des Zinnes.*) When the rod is bent backwards and forwards for a considerable time, it grows warmer and warmer, until the heat becomes too great to be borne by the hand. By being thus bent, the connection of the separate parts of the tin is disturbed, and the changed state of the metal, in relation to that connection, is communicated from one point to another of the whole mass.

When two plates of metal, stone, or wood, are laid, one over the other, and friction is produced by moving one quickly and powerfully over the other, it becomes manifest that the generation of heat is caused precisely in the same way as in the tin rod when it is bent as above mentioned. In the two bodies there is occasioned a mutual attraction of the near surfaces, a change in the cohesion of their component particles, whose agitation becomes a vibratory motion like that of stretched, musical strings. Even the circumstance, that of two plates rubbed together, that is more heated whose surface is roughened than that whose surface is smooth, renders it perhaps probable that the heat produced is more easily taken up by the unevenness of the former plate, like electricity by metallic points.

That vibratory motion, which is caused by rubbing the finger on the glass bells of an harmonica, and which, by being communicated to the air, is transmitted to the ear, so that we perceive it as a musical sound, may also be produced by striking the glass or metal bell. For a blow acts precisely like friction upon the cohesion of the atoms of the glass or metal. In the same way, heat is generated by striking. An iron rod, by being merely hammered on an anvil, may be heated red hot. When steel and flint are struck together, so great a heat is produced that the little particles of steel which are broken off, not only become red hot, but melt, for the little black particles which are thrown off and may be gathered up, when examined

by a magnifying glass, appear as little melted balls of steel. When two stones are struck against one another, the minutest pieces which are struck off, are red hot. Fulminating powder explodes at one powerful blow.

In most of those cases, in which heat is generated by a blow or by pressure, it is evident that the bulk of the body, struck or pressed, is lessened. A copper plate, which was used in the making of coin, showed after the first pressure of the stamp an increase of heat of almost $9\frac{3}{4}$, after the second $14_{\frac{7}{8}}$ degrees. But at the same time it had also suffered a diminution of its bulk, for its density and its specific gravity had increased in comparison with the specific gravity of water from 8.86 to 8.91. A silver plate, submitted, in the same way, to the coining process, was heated only about 8 degrees, but its density had increased also, only from 10,467 to 10,484. Gold under the pressure of the die undergoes a less change of density than silver, but it is also heated still less. On the other hand, in the sudden compression of the air in the tube of the fire-pump into about a fifth of its original bulk, a heat is produced, which sets fire to a piece of spunk placed therein; and in a similar way heat is produced by the compression of a gas.

In the case of these gaseous fluids, the generation of heat by compression is especially related to their elasticity. Water has but a very small degree of elasticity, and under the strongest pressure can be condensed only very slightly; for which reason, pressure upon water and similar fluids produces no perceptible amount of heat; very different, however, is the case when water has passed from its liquid form into the form of steam. When this change has been effected by the boiling heat of 80° Reaumur, (212° F.) it is observable that the hot steam cooled again by the cooler bodies surrounding it, so as to lose the gaseous form and again become water, communicates to the surrounding air a heat, which corresponds to $424\frac{8}{10}$ de-

grees R. (1000° F.) (531 of the centigrade scale.) This fact has been made use of, not only in the construction of the hot-houses of the gardeners, but also in the warming of rooms and whole buildings by the steam of boiling water which is carried in cast-iron pipes through different rooms under floors and in the walls; and the water, which, in its conversion from steam, is still at the boiling point, is caused by pipes, arranged for that purpose, to return again to the boiler, which it reaches still tolerably warm. With a pound of steam continually formed anew, the rooms and halls of a building, comprising a space of 1000 to 1200 feet, may be warmed in winter.

But water is converted into vapor not only by boiling, but it also passes into the form of gas at the lower temperatures of our autumn and winter days. But in order to this, there must be the influence of heat, as in boiling; and when it returns to a liquid state it also gives out heat. This is manifest in winter by the diminution of the cold previously to or at the commencement of a fall of snow, and in summer by the oppressive heat of the atmosphere before a gust and shower. Out in the open air, however, when steam is generated, there are quite other spaces to be heated than the rooms of our dwellings. There the heat, produced by the conversion of a pound of steam into a pound of water, is communicated not only to hundreds, but to thousands and hundreds of thousands of cubic feet; and the process itself takes place so gradually, and is so distributed in space, that we perceive its effect upon the temperature of the atmosphere less by our senses than by our calculations.

The reverse process, however, the taking up of heat from the surrounding material objects, in the conversion of water into vapor, comes more distinctly within the range of our senses. The seaman, when he wishes to know, in an apparent calm, which way the wind is, moistens his finger in his mouth, and holds it up in the air. The sensation of coolness, stronger on

one or the other side of his finger, tell him whence the wind blows, which evaporates the moisture. Thus, whenever water evaporates, whether when it rains or when we bathe, or when it appears as perspiration, we experience a sensation of coolness and even of cold, and we can produce a lower temperature on our bodies by a conversion of water into vapor or gas. For as, after every shower, a feeling of coolness is experienced by the evaporation of the rain that has fallen; so, on a small scale, we may moderate the oppressive heat of the sun, by sprinkling the floors of our rooms with water. In the hottest season of the year, the inhabitants of Egypt cool the water which they drink, by filtering the luke-warm water of the Nile, in a kind of earthen vessel of great antiquity. The clay of which these jars are made, and which hardens in the sun, is not water tight, like our glazed vessels, but the water permeates through its walls by means of innumerable little openings, imperceptible to the eye. The surface thus remains in a constant state of moisture; and, while a part of the water forming the moisture, passes into vapor, and a proportional degree of heat is taken up from external objects, such a coolness of the vessel and its contents is effected, that the drops, which gather on the outside and run down into a vessel placed underneath, afford a drink as cool as the water in which the Neapolitan puts his piece of ice. In the East Indies, wine and other liquors are cooled, by being put in bottles over which is drawn a cloth of the quality of our knitted stockings. By keeping this cloth constantly moistened, an evaporation is kept up, by which a very considerable degree of coolness is produced. In a similar way the inventive European, dwelling in those countries, cools his room, by hanging before the openings of his door and windows, mats, woven of the sweet smelling Cuscus, (a sort of cypress grass,) and kept moist by being constantly sprinkled with water, and thus promoting a steady evaporation. By another contrivance also by

which wet layers of rice-straw upon a frame work of poles or rods create a fresh draught of the cool night air, the inhabitants of the hottest regions of the East Indies obtain a means of coolness, similar in its effect to that of the snow kept in artificial ice houses, by which the affluent classes in Europe are enable to procure the refreshment of their so-called "ices."

It is a fact of daily observation, that, in passing from a greater degree of density to a less, a body becomes cooled, and that, when the bulk of a body is reduced in size, heat is generated. The air which we compress in our air-guns, or in a fire pump, to a fifth of its previous bulk, and which thereby gives out heat sufficient to set a combustible body on fire, would seem to show that heat is a substance, like the water in a spunge, contained in the little interior invisible spaces between the atoms of bodies, and that by mechanical means, it may be driven out from this its residence, and made perceptible by our senses. It even seems to indicate that it is from the essential substance of heat that material things receive and maintain their respective forms. There is, however, in this representation, when we lay aside this mode of expression, and employ another and more appropriate way of speaking, as much of error as truth. This will be more evident in the sequel, when we have first considered more particularly some other properties and effects of heat, and the most common and most effectual methods of generating the same.

When a pound of water of 212° F. in temperature, is mixed with another pound of water which has been reduced to 32°, or the freezing point, then the temperature of the mixture is between the two, 122°. When, on the contrary, a pound of iron filings, heated to 212°, is put into a pound of water standing at 32°, the water receives only 18° of heat, and the iron must be heat 1976°, if the temperature of an equal weight of water is to be raised to the boiling point. In a mixture of heated

mercury and cold water the proportion is yet more striking, for if a pound of mercury heated to 167° is mixed with a pound of water, whose temperature is 32°, only a heat of 4° is communicated to the water by the hot metal. Still more sparing than in the case of mercury, is the communication of heat by heated gold and rolled platinum, or even by lead, or bismuth, for, while a pound of ice may be melted by a pound of water at 172°, it requires 30 lbs. of mercury, heated to the same degree, to melt a pound of ice, but of gold, platinum, lead, bismuth, about 31 to 33 lbs. Nevertheless, it is not density alone, and the specific gravity connected therewith, upon which depends the greater or less degree of heat, which bodies can take up from without, and in their turn communicate to other and colder bodies, for, in its capacity for heat, lead is inferior to gold and platinum, and the much lighter metal bismuth stands below gold, and lead also. In like manner tin, and still more antimony, have a lower capacity for heat than silver, although they are both perceptibly lighter. On the other hand it is well known that neither lead nor tin experience any change in this respect from being hammered, because they do not, by this operation, become denser or specifically heavier, like copper, silver, and even gold. That in one and the same substance the capability of taking up heat is greatly dependent on its condition, or the arrangement of its particles, is shown from a consideration of carbon. This quality in pure crystalline carbon, in the form of diamond, does not amount to $\frac{3}{4}$ths of the capacity of heat of plumbago, nor to $\frac{5}{6}$ths of the capacity of charcoal. Between the diamond, however, and common carbon, there exists a real difference extending to the inmost nature of their composition, but that the mere increase or diminution of density or bulk affords no test of capacity of heat, but that other things are to be taken into consideration, is best seen in those bodies, which of all bodies are susceptible of the highest

degree of change in regard to density, the gases. The capacity of gases to receive heat changes with their elasticity. And as every compression disengages heat, it follows that the capacity diminishes according to a certain law, according as the pressure increases.

One of the most familiar and thorough changes of form, produced in bodies by the influence of heat, is the melting of the same. When a pound of ice is put into a pound of boiling water, the ice melts and the heat of the water that is produced rises 22.5 degrees, 135° of the heat of the water are of course used in the melting of the ice; such a quantity of heat has just sufficed to give to the newly formed fluid the temperature of 32°, the superfluous 45° of heat increase the temperature of the two pounds of water to 22.5 degrees throughout. A piece of ice, while melting in the hand, always keeps the same coldness, because all the heat, which it receives from the hand, is employed to change it from a solid to a fluid state. For this reason a leaden ball, wrapt smoothly in paper, may be held over a lighted candle until it melts without setting fire to the paper; the influence which the heat of the flame exerts on the fusible body is all taken up by it until the moment that it changes its form and melts.

The reverse is the result in the change of a body from a fluid to solid. When so much Glauber salts is dissolved in boiling water as the water is able to take up at a temperature of 212°, and this saturated solution is sealed up air tight, and placed in a quiet place, it remains fluid until it is shaken, or brought into contact with a solid body. But the moment this happens the fluid passes into the state of a solid, and thus a very perceptible degree of heat is generated. A similar fact is observable when chloride of calcium passes from a fluid to a solid state. In the slow freezing of water, we are not indeed sensible of the rise of the temperature, which, in a quicker pro-

cess of change, would amount to 135°, nevertheless, that there is such an increase is manifest in the fact, that water, which before becoming ice is cooled about 9° below the freezing point, (32°) in the instant of freezing rises again about 9°, and keeps at this temperature during the process of changing.

That heat which a body takes to become fluid is denoted by the name of *latent heat*, which, in the solidifying of the body, is again delivered from its bondage.

30. THE CONDUCTION OF HEAT.

When a piece of metal is exposed at one point to a melting heat, the metal begins to become fluid, or to melt at that point, but the change of form soon extends to the whole mass; while, on the other hand, a piece of sugar applied on one side to a flame, melts on that side, without the communication of heat, in any perceptible way, to the other side. A shaving of wood may be burning at one end, while the other end is held in the hand with ease. A piece of iron of equal length, on the contrary, one end of which is made red hot in the fire, receives a high degree of heat at the other end, and in a rod of gold, the extension of heat from the end heated in the fire to the other end, is still more observable. In like manner, if we put one end of a rod of iron, or still better, of gold, into snow or ice, the other end very soon takes a very low temperature, while a rod of wood, in a similar case, only very slowly, and scarcely perceptibly, cools at the upper end. This difference in bodies is based upon their power to communicate the heat which they receive in one part to their other parts and to all around them, in other words, upon their power of conducting heat. A body which quickly and easily transmits the heat (and the cold) which it receives from without, through all its parts, and to other objects coming in contact with it, is called a good con-

ductor of heat, while other bodies, that possess this power in a very limited degree, are called bad conductors.

If, instead of our clothing of linen or woollen, we should wear garments of metal, the cold air in winter, the sun's beams in summer, would be insupportable. Such a covering would quickly carry off and dissipate in the surrounding air, the animal warmth of the skin, at the same time affording as ready admission of the external heat and cold. This influence of the best conductors may be witnessed in the attics of those buildings, the roofs of which are covered with lead; the prisoners who were formerly confined in Venice under such leaden roofs, had to bear a summer's heat, which drove many of them mad. Roofs covered with shingles or straw, instead of tiles or slate, afford a better protection against heat and frost, because they are bad conductors.

Those natural coverings which are provided for animals in their feathers, or their hair, and those stuffs from which man has learned to prepare his garments, are more or less imperfect conductors of heat, according to the season and the climate; and even snow is, in a degree, of this character, and thus becomes a protecting cover to the seed against the severe cold of winter. To protect the feet from cold, the rider wraps his stirrups in straw. We put wooden handles to metallic vessels. We cover the floors of our rooms with woollen. The gardener protects his plants from the cold by wrapping them in straw. That which guards against cold, protects from heat also. On the burning sand-plains of Persia, the horseman guards himself from the parching glow of the summer's heat by clothing himself in a light skin,—the same means are used by the inhabitant of Siberia, against the cold of winter.

On the whole, bodies of the greatest density, the metals, are the best conductors of heat, yet there is a great difference among them in this respect. Gold conducts heat 2¼ times

better than iron, about 6 times better than lead. Still greater, however, is the difference, when we compare the non-metallic bodies with gold. Marble is 42 times inferior to gold in conducting heat, porcelain 80, burnt clay (brick) 90. The organized bodies formed out of gaseous substances are, for the most part, incomparably worse conductors of heat than metals and stones, yet it is observable of the different kinds of wood that they transmit heat somewhat better lengthwise of the grain than across, whence it comes that plants more readily attract heat from the soil than the surrounding air.

In the case of liquids and gaseous fluids, which belong comparatively among the bad conductors of heat, there is another circumstance to be considered, which has an effect upon the process of the transmission of heat, thus far considered. By virtue of the greater mobility of their parts, wherein the chief peculiarity of fluidity consists, the lighter particles mingle with the heavier, the less dense with the more dense. As now, as we shall yet further see, the heat acts with an expanding influence especially upon fluid bodies, and consequently makes them at the same time lighter; not only does the heated air, with which we fill a mongolfier, rise into the colder and consequently heavier air, carrying up the air-ship along with it, but, when we mix any pulverised substance with a transparent fluid, we may see rising before our eyes hundreds of thousands of little mongolfiers. When the fluid is heated from below, the particles of the powder rise in whole rows with the particles of the fluid, which have become lighter by the heat, like the air-bubbles which the carbonic acid forms in champagne wine. The fluid contained in a vessel standing over the fire and heated at the bottom, rises from below upwards into the colder and denser portions, through which it carries the heat along with it, until at last the whole has reached the boiling point, and then the conversion of the liquid into air is the result. As it is the

easiest way to communicate heat to all fluids from one layer or portion of the fluid to another, water, like every other fluid may be made to boil more quickly when the flame, or heated metal plate, by which the heat is generated, acts from below upon the bottom of the vessel, than when the heat acts on one side from a fire kindled on the hearth on which the vessel stands. But the most difficult thing of all always is to heat a fluid from above downwards, because the portion of water at the top remains, as the lighter at the top, and the low capacity of fluids to conduct heat extends the heat to the lower strata only very slowly.

Something similar to the case of water, which is heated from below, we experience every winter day, in the warming of our rooms. The air, which is warmed in the vicinity of a stove and so rarefied, rises towards the ceiling, and the cold air, which is also heavier, sinks down. When the latter, colder stratum has reached the heat of the former, it also ascends, and, if we are not sitting where we can feel the heat radiated from the stove, we feel little of the warming of the room, until all the portions of the air have reached that degree of heat and expansion, at which the descending of the cold, dense strata of the air loses its chilling influence. When public places, theatres for instance, are heated by common stoves, the spectators who sit in the galleries are oppressed by the heat, while those below suffer the opposite sensation of cold, from a continual draught of the colder and heavier air.

The constant streaming of warm air upwards and of cold air downwards, has been taken advantage of in a mode of heating our dwellings, which is well known, as it has come into very general use. In a small chamber built for the purpose, (the air-chamber) the air is heated by means of a cylindrical stove, and then carried by tubes or flues into the rooms, which are to be warmed. The flue communicates with the air-cham-

ber at a height of from 4 to 5 feet from the ground, but below, at the bottom, there are other openings by which cold air is introduced; when a tube or pipe is carried through an ordinary stove, both openings of which, one below and the other above lead into the room, then a similar draught of the cold air upwards is produced, and the warming of the room is not a little assisted.

In the consideration of this subject, the conduction of heat by fluids, we come to a property of heat which, for the understanding of the phenomena of nature and for manifold purposes of human economy, is of the greatest importance. This property is, the expansion even of solid bodies, but of fluids more particularly, under the influence of heat. In the case of several substances this expansion takes place in such a steady proportion to a gradually increasing heat, up to the boiling or to the freezing point, that they have long been used in the construction of heat-measurers, or thermometers. The use of the instrument, now mentioned, is of such value to science and the practical purposes of life, that its consideration claims of us a special chapter.

31. THE THERMOMETER.

In Egypt, as is well known, chickens are hatched out, not by the mother-hen, but in ovens arranged for the purpose, in which the floor, as well as the air of the oven, is moderately warmed by a small fire kindled at different points at different times. If, in this business of hatching eggs, the powerful heat of the sun were wanting, the Egyptian peasants would find all their labor lost. They would be compelled to give up all the profit and all the pleasure which their brooding ovens afford them, in which, oftentimes, several thousands of eggs are hatched at once. The roof and the walls of the clay-built

oven are warmed outside by the sun's rays as much as inside by the air which is heated by the fire, and the regular heat of the sun is at least as much reckoned upon as the heat which the fire gives. On this account the brooding ovens are not prepared for use earlier than towards the end of March, or in April, because then the days are sufficiently warm. And when now from one division of the oven, which was first filled with eggs, then from a second and a third, &c., oftentimes hundreds of chickens are taken out on the 21st day of the artificial brooding, and after being kept a day perhaps in the lower rooms of the brooding house, are let out into the open air, then, there also the sun must supply the place of the warm maternal feathers, and this place it fills so effectually, and with so great a degree of heat, that in the hottest hours of the day, the tender creatures are as eager for the shade as the chickens raised among us in the natural way are, when a raw wind blows, for the protection of the maternal wing.

If any one is disposed to try the experiment and hatch eggs artificially, which may be accomplished by a spirit-lamp, placed under a small brooding oven, or, if the oven is large, by several lamps, care must be taken that the eggs maintain a warmth which is neither too great nor too little. The due heat is about the temperature of our blood; on which account, persons who are compelled by a broken leg, or some not dangerous accident, to lie in bed for a space of time, may amuse themselves with hatching an egg, by placing it perhaps in the pit of the arm. The warmth which the body of a brooding hen gives out, is, however, somewhat greater than the vital heat of the human body. Hence it is not injurious to the developement in the eggs deposited in our small brooding ovens, if the temperature is a little higher than that of the body.

But precisely the due warmth—how shall we determine and measure it? By our feelings? But how different at different

times, and under different conditions of the skin, is our feeling in regard to one and the same degree of temperature! The air of our rooms on a winter's day, seems almost too cold to allow us to remain in it with comfort; we go out into the open air and take exercise, and then return to our rooms, and the air is felt to be agreeably warm, perhaps too warm. Or we step out of the inmost apartment of a Turkish bath, in the water and steam of which we have been bathed,—we step out into the adjoining room, and the air strikes us as pleasantly cool, although it is in fact so warm, that in another condition of the skin it would seem to be intolerably hot. That deception to which in this case the whole surface of the body is subjected, is, in a small way, put upon us when we try to estimate heat merely by the finger or hand, as the nurse may know, who in preparing water for a child's bath, measures the heat by the feeling of her hand, and learns from the quick and sudden cry of the child, that what is warm to her is cold to the child. How perilous would it be to the sick, who depend upon being kept in one uniform temperature, if the due temperature could be determined only by the feelings of the healthy; or how would it fare with the eggs in a brooding oven, if we had only this uncertain measure of heat. In these and thousands of other cases, it was long a desideratum to ascertain a method of measuring heat, which is liable to no such errors.

A countryman of Alkmaar, in North Holland, *Cornelius Drebbel*, whose great ingenuity had previously been shown in other ways, appears to have been the first who came out before the world with a Heat-measurer, invented by him in 1638. His thermometer was simple enough, and had various defects. It consisted of a glass ball at the top of a tube, the lower and open end of the tube being placed in a vessel filled with water, colored by a solution of nitrate of copper. At the usual temperature, the fluid rose, through the attraction of the glass, to

a certain point in the tube, but when the air in the ball above expanded under an increase of heat, the fluid was pressed down; when the air in the ball was contracted by cold, the fluid mounted higher in the tube. But apart from the circumstance that the degrees of heat of the rising or falling of the fluid were very imperfectly determined, the fluid in the vessel was also exposed to the changing pressure of the atmosphere.

These defects were removed by an improvement upon the thermometer made by the Florentine Academy del Cimento, some years after, and which came into general use in 1693. The Florentine thermometer is substantially the same now in use. It consisted of a glass tube, the upper end of which was closed and melted together, the lower end terminating in a ball. Instead of mercury, which is now employed, the Florentine thermometer contained, and still contains, where it continues in use, colored spirits of wine. In an increasing heat this fluid expands, in cold it contracts, and thus indicates both changes of temperature by rising or falling in the tube. To this improvement a professor in Padua, *Renaldini*, in the year 1694, added yet another. The thought occurred to him of employing the freezing and boiling points of water as the two limits, between which the rising or falling of the spirits of wine was measured by a scale of degrees. Another celebrated man of science, *Halley*, proposed the use of mercury, or of the air enclosed in a ball, which, by its expansion acts upon the quicksilver, which is contained in a long tube terminated with a bulb.

All the inconveniences to which this and other thermometers then in use were liable, were obviated by *Daniel Fahrenheit*, an ingenious mechanician, born in Dantzick, and afterwards citizen of Holland. The same severe winter of 1709, which occupies such a place in the account of Duval, helped this ingenious man to the invention of a thermometrical scale, which is used by the English to this day. The cold, which

at that time prevailed so long, even in countries where the influence of the vicinity of the sea tempers to a considerable degree the severity of winter, Fahrenheit learned to produce artificially. He had remarked that in a mixture of sal-ammoniac and snow in equal quantities, even in a warm room, the spirits of wine in a Florentine thermometer sank just as low as it did in the open air in the winter of 1709. Thus a fixed point for the division of his thermometrical scale was found, which every one could certify with but little trouble. A second point for graduating the rising of the thermometer, tolerably certain, was still more easily to be had in nature, because every healthy man carried it in himself. This second point is the natural warmth (blood heat) of the human body, which is most easily discovered by placing the bulb of the thermometer under the tongue and allowing it to remain there 10 or 15 minutes. The observations made in regard to this point upon the inhabitants of different regions and climates, have shown only a very slight difference. The Malays in Ceylon, the inhabitants of Siberia, the Hottentots in Southern Africa, and the Esquimeaux in Greenland, the wild, naked Vaidas, who inhabit the forests of the Indian peninsula, and the well clad European in his palace, all have, with only slight variations the same blood heat, from a little below to a little above 97¼° F., 29° Reaumur. And if some scientific men are disposed to ascribe to the continued effect of a hot climate the power of raising the warmth of the blood a degree of the thermometer, there are others again, who maintain that the Esquimeaux show a higher blood heat than the negroes on the gold coast, a difference of opinions which can only be settled by subjecting to examination, not the external heat given out by the body, but the internal temperature as ascertained in the mode above mentioned. The skin of the negro, under a degree

of heat insupportable to the European, feels cool, because the internal blood heat is tempered by the increased evaporation from the surface. The skin of the Esquimeaux, and the exhalation of his breath diffuses in the enclosed space of a small room a heat, which, when several of these people are together, makes a stove unnecessary; but the blood heat in both is scarcely perceptibly different; and even in the case of the sick in the most violent fevers, the heat of the blood rises at the highest about 9° F., 4° Reaumur. But, after all, this second natural degree of Fahrenheit's thermometer is far from being as fixed as the first; as we have said, it is only tolerably certain. For slight variations of the ordinary degree of blood heat show themselves, even in the same person, in unmistakeable ways. The time of life, internal or external excitement are not without influence, and the fact that Fahrenheit divided the distance between the cold of his mixture of sal-ammoniac and snow, and the heat of the human blood, into only 96 degrees, (instead of 98 and 99) shows that he has placed the heat of the human body too low; probably because he applied the thermometer by which he sought to measure it only to the palm of the closed hand, or to other parts of the external surface of the body. Three other standard points for the division of the scale were regarded by him as universally true: the melting point of ice, the boiling point of water, and as the extreme limit, the heat at which mercury boils, or is converted into air. From the average degree of cold in the winter of 1709 to the temperature at which water freezes, Fahrenheit counted 32 degrees of his thermometer, to the boiling point, 212°, to the boiling point of mercury, 662°. To discover this highest degree of heat ascertainable by the mercurial thermometer, we do not have occasion for the help of such a frail standard; accordingly, for ordinary use a shorter glass tube, showing the increase of heat

only to the boiling point of water, or not much higher, has been preferred to the tube so inconveniently long, whose scale counts upwards of 660°.

The great advantage possessed by mercury next to air, as a fluid for the tube of the thermometer, was justly recognized by Fahrenheit. Mercury, as an excellent conductor of heat, is vastly more susceptible to the changes of the temperature than other fluids. It is much more easily obtained in a perfectly pure state than perhaps spirits of wine, which, even when prepared with the greatest care, often contain air as well as other admixtures. A great degree of cold renders it thick, and under the higher degrees of heat it expands inordinately. It is true mercury freezes at a cold which is 72° F. 31⅕° of Reaumur below the freezing point of water, and can then no longer be used to ascertain still greater degrees of cold, but, in freezing it does not expand to a greater bulk like water, and in such a case also the reliance upon alcohol for the measurement of cold does not go beyond a certain degree.

With all these decisive advantages which air and mercury have, as measurers of heat, over spirits of wine, the latter found nevertheless, a new advocate in the French philosopher, Reaumur. As the name of Americus Vespuccius has been given to the world, the glory of whose discovery belongs rather to Columbus, so is Reaumur's name given to our thermometers, although they are made according to Fahrenheit's method, and filled like his with mercury. The careful and exact Fahrenheit owed all his knowledge to his own observation; he was not properly a man of science, but simply a mechanic. Reaumur, on the other hand, had the reputation of learning. He took great pains, however, in determining the two extreme points of his thermometer, which required that the precise moments should be fixed, when water changes its form, the melting and boiling points. In a glass tube 2 feet long, with a bulb over 2

inches in diameter, he put spirits of wine, the strength of which had been proved by its kindling gunpowder, and which had then been diluted with a fifth part of water. This fundamental thermometer was sunk in a vessel of water, surrounded by a mixture of salt and ice. At the moment when the water in the vessel was so far cooled as to begin to freeze, the point, at which the spirits of wine stood, was carefully marked. The boiling point was determined by putting the thermometer in boiling water. With the greatest exactness, the alcohol in the instrument, was, in the state of expansion in which it was at the freezing point, measured off with little cups, and in this way divided into 1000 equal parts. In order that, at this low temperature, and in this slightly expanded state, it might fill the glass tube just so high as at its greater expansion at the boiling point, 80 little measures or cup-fulls had to be added, increasing the whole quantity from 1000 to 1080. This furnished the basis of the division of Reaumur's scale into 80 equal degrees.

It was in the year 1730, that the celebrated Reaumur described the thermometer, named from him, in the most widely circulated publications of France, and immediately suggested that smaller thermometers should be made for common use, the scale of which might suffice to determine the temperature of different countries and seasons, as well as that of fluids up to the conversion of water into steam. The natural advantage of his fixed point, which is obtained without artificial means, together with the great reputation of the man and of his country, obtained him an easy, although not strictly a universal victory over his rival, Fahrenheit, to whose artificial zero point there is certainly much to be objected. The countrymen of Reaumur, mindful of their national honor, spared no pains to hide and keep out of sight the great defects caused by the use of spirits of wine instead of mercury. Among other things it

was sought to conceal the unequal expansion and contraction of spirits of wine in comparison with quicksilver by lessening, according to no very exact calculation, the degrees which were above 40 and below 0, on the 80 degrees scale of thermometers, filled with mercury. The honest truth, however, at last cleared a way for itself. It was found necessary to make thermometers, and to fill them according to Fahrenheit's well tried method. Reaumur's division, nevertheless, still kept its ground and for those great degrees of cold, at which mercury becomes solid, alcohol was still used.

The degrees which Fahrenheit established and employed in his thermometers, admirable for their exactness, are less than those of Reaumur's scale. Nine degrees of Fahrenheit amount to only 4 of Reaumur; $2\frac{1}{4}$ degrees of the former scale are equal to 1 degree of the latter. Fahrenheit's zero falls upon a degree of cold, which lies somewhat more than 14 degrees below the zero of the scale of 80 degrees; this latter, the melting point of ice, corresponds to a heat of 32 degrees of Fahrenheit. If, therefore, a degree of heat is indicated by Fahrenheit, which exceeds 32, 32 must be subtracted from it, and the remainder be divided by $2\frac{1}{4}$, and thus the corresponding degree of Reaumur will be ascertained. Thus, for example, 77° F. correspond to 20° R. for 32 subtracted from 77 leaves 45, and this sum divided by $2\frac{1}{4}$ gives 20; 50° F. are 8° R.; 122° F. correspond to 40° R. On the other hand, when the degrees of the F. scale are below 0°, 32 must be added and the remainder divided by $2\frac{1}{4}$. So it is found that 13° below 0° F. are equal to 20° R., 22° below 0° F. to 24° R. For 13° to 32 give 45, 22 to 32 give 54, and these sums divided by $2\frac{1}{4}$ give respectively 20 and 24.

These two methods of determining degrees of heat, have maintained themselves in use, dividing their popularity in the wide domain of national customs. A third method of dividing

the scale, however, has more recently won such general attention, that perhaps it will attain to exclusive empire, and come to be adopted by all European nations. It is the method of the learned Swede, *Celsius*, who divides the interval between the melting point of ice, and the boiling point of water,* into 100 parts instead of 80, so that 50° of heat on this scale correspond to 40° R. and 122° F., 4° Reaumur are equal to 5° Celsius, and 9° Fahrenheit.

In order to measure a greater heat than that at which mercury is converted into steam, and becomes incapable of measuring heat further, which is the case at 350° of Celsius, 280° R. and 662° F., attention has been turned to the expansibility of Platinum by heat, because this metal is one of the most infusible. The points at which the metals become fluid, have also been taken as fixed points, in order to determine the strength of fire, and in this way many points, instead of one, have been obtained for pyrometry, or the measuring of the heat of fire. A little piece of metal, of the size of a pin's head, which can be used, not only once, but in the case of gold, silver and platinum, the metals with difficulty oxydized, upon every new trial, suffices for the purpose. The melting points of silver and gold lie about 10° apart, the first of these degrees is that, at which a mixture, 9 parts silver and 1 of gold. the second that, at which a mixture of 8 parts of silver with 2 of gold, is fused. Between the degree, at which pure gold, and that at which pure platinum melts, 100 degrees are divided off, and these so made that 1, 2, 3, 4, &c. hundred parts of platinum are mixed with 99, 98, 97, 96 per cent. of gold. Besides this, there are

* These are the two reliable points for graduating thermometers. The height of the barometer should be observed when the boiling point is fixed, as the pressure of the air has an influence on the temperature, at which water boils.

scales extending still farther for the easily fusible metals. Silvan ore melts at 362° of the Fahrenheit scale, tin requires 442, lead 612, zinc 773, copper 1996, gold 2016, cast iron 2786 degrees.

We have dwelt somewhat at length on artificial measures of Heat. The Thermometer, together with the Barometer, among all the inventions of science, has, not only become of general use in the practical pursuits of life, it has proved man's valuable attendant through the various climes and countries of the world. To it alone we owe the knowledge we have obtained of the differences of climate in different regions and heights of the earth, the information possessed of the variations in the average heat of seasons and days; and what we are able still further to say respecting heat and its effects would greatly lack precision, if the means were not at hand to measure its power.

32. THE FORMATION OF STEAM BY HEAT.

Two centuries have now elapsed since, by the invention of the barometer and thermometer, a wholly new path was opened to the investigation of the heights and depths of nature, as well as to a more intimate knowledge of that natural power, which may be regarded as the great mother and nurse of physical life. We are now so accustomed to the use of those two scientific instruments, that we can hardly understand how men got on in old times in the domain of science without those aids. And yet then, when neither the Barometer nor the Thermometer was known, the air by its pressure formed just as happy an equilibrium with the elasticity of material bodies as now, the sun's rays called forth the verdure of the meadows with the same force, and ripened the seeds of the grain and the berries of the vines. These inventions have operated directly only upon the intellectual activity of man, animating and elevating

human science. They have wrought no change upon the physical conditions of man and of nations. But there are other inventions of modern times, which, in their relation to daily life, have exerted such an influence, that hereafter men will find it difficult to understand how men could have lived on the earth without the helps now at our command. Among the inventions, which have sprung out of the soil of science, and spread their branches over all the employments and pursuits of man, belongs especially that of steam engine, by means of which, man has gained power over one of the strongest moving forces of nature. Fahrenheit, when he invented the artificial zero-point of his thermometer, learned his art from the severe winter of 1709, by which land and water were filled with the horrors of frost. The inventors of steam engines have made their own the art of the volcano, by which the stone masses of the depths are hurled upwards to a height of thousands of feet, rocks are shivered, and in the centres of plains, new mountains are formed, and piled up to the regions of perpetual snow.

One of the profoundest and most comprehensive philosophers of Germany, Leibnitz, amused himself in his leisure hours with inventing all kinds of mechanical contrivances, to set carriages in motion without horse-power, merely by the agency of some internal machinery. His acute mind failed of the discovery, which the inhabitants of every little American village have, in these days, at their command: the discovery of the means of forming an alliance with the power of steam that rises unused and unmarked from every boiling pot, from every washing kettle, by which it becomes possible for human art to surpass the horse in speed, and to overtake the wind in its swift career.

In the middle ages, when most of our rivers were scantily provided with bridges, and the mountains and hills were covered with forests, the vallies and plains, filled with moors and quicksands, the wagoners, who traversed Bohemia, or who came from

France to Gosslar, occupied weeks ere after many circuits and thousandfold difficulties they reached their journey's end. Even in later times, when roads were made over mountains and through forests, over land and stream, but not having the excellence of our present highways, a long journey by land was more a toil than a pleasure, while the traveler now-a-days, comfortably seated in a steam-car, accomplishes in a few hours a journey which would take a foot traveler several days. And traveling by water has been still more facilitated than by land by the use of steam. The success of a sea-voyage depended in earlier times almost entirely on wind and weather. The passage from Smyrna to Alexandria was formerly accomplished with a good wind, sometimes in 4 or 5 days, at other times in a calm or with a contrary wind it took 30 days. The seaman found himself in sight of land, expected every moment to reach it, but could not run into the harbor because the wind had left him, or setting in from the land had driven him out again to sea. Now men embarking in a vessel whose progress depends upon no external force, but upon the internal impulse of steam, dart like the sea bird, against the wind, and are impeded by no calm, they can determine with great certainty beforehand the time it will take to pass from one harbor and from one continent to another.

Wherever we look in these days we find steam performing in the service of man labors which formerly demanded the strength of many arms, the power of many horses. If we ask who draws the water and the metal from the depths for the miner, who sets the wheels of the weaver in motion, the answer is: It is steam. Steam helps us to pull down and build up, to lift and to carry. It is steam also that gives motion to our printing presses.

How enormous is the elasticity of gaseous bodies when, released from the pressure which holds them in check, they im-

mediately become free, as when any solid or liquid substance takes the gaseous form, the effect of gunpowder long ago showed. Saltpetre is, as we have already said, a combination of potassa with nitric acid, but this, on its part, consists of a combination of the two main ingredients of the atmosphere, nitrogen and oxygen, (which through mutual cohesion have parted with their original form as gases, and taken a liquid state.) Saltpetre forms in weight the main ingredient of gunpowder. To make 100 lbs. of gunpowder, 76 lbs. of saltpetre must be mixed with 15 lbs. of carbon and 9 lbs. of sulphur. If, instead of weight, we consider the volume of the two atmospheric gases before they take a liquid form, we shall be reminded of the oriental tale of the giant who was confined by magic in a little box, and whom a fisherman, having dragged the box out of the sea to his own imminent peril, released from his narrow prison. Human art, in the preparation and use of gunpowder has to do with such a giant force, confined in the little space of a particle of the powder, a force which only too often when least expected, has exerted against man its destructive energy. For when gunpowder is inflamed perhaps by a spark of fire, the carbon and sulphur combine, not as they do in the open air with the oxygen of the atmosphere, but with the oxygen which in combination with the nitrogen formed the nitric acid of the saltpetre. The powder takes fire, therefore, instantaneously; sulphuric acid and carbonic acid are formed; the first remains in combination with the potassa of the saltpetre, but a part of the carbonic acid immediately take a gaseous form with the nitrogen, and these two gases whose ordinary average volume is increased by means of the heat produced by the combustion of carbon and sulphur, now expand in an instant to many thousand times the bulk of their solid state. As to the part taken by the several ingredients of gunpowder *in the violent* agency of the same, the sulphur serves to make

the powder easily inflammable, while the carbon contributes essentially to the force of the explosion by partly taking the form of carbonic acid. A mixture of carbon and saltpetre simply would give a gunpowder of still greater strength, but not so easily and certainly inflamed. Thus it is only the conversion of the solid and fluid states of some of the components of the powder into gases, and their powerful expansion by heat which mainly produces the explosion.

How much man is indebted in war and in peace, to this ally that his art has secured, it is scarcely necessary to mention. The terror which renders man the master of the animal world has been greatly increased since the introduction of fire-arms, for a bullet passes through space in its full force ten times quicker than the eagle, thirty times quicker than a race-horse, and the speed of a cannon ball in the first second of its discharge is more than one-half greater than the ball of a good musket, the former amounting to nearly 2,300, the latter to about 1,400 ft. And with the speed communicated to the ball of a musket or cannon there is connected the enormous force with which the ball or stone penetrates the body which it strikes. If the pebble, the weight of which resting in the hand could scarcely be felt, when hurled by the shepherd boy from his sling, had power to prostrate to the earth the giant into whose forehead it sunk; how much greater must be its force when impelled by gunpowder. The human arm can communicate to a stone thrown from the hand with its utmost force, a speed equaling that of a gale of wind, (53 feet in a second,) and a sling may double this speed; but the rapidity with which the ball is discharged from a musket is ten and even fourteen times greater; and that it is that gives to a tallow candle, discharged from a fowling piece, power to penetrate a board or several thicknesses of leather. Thus in the moral world, the rapid and powerful resolve, *the mighty inspiration* of one individual, will

work wonders when it seizes and sets in motion the sluggish masses of a nation.

Still although the fire-giant that sleeps in gunpowder must toil in the service of man, blowing up rocks and discharging the destructive offices of war, yet we have here a terrible auxiliary. A common musket even may peril limb and life, when in loading it we carelessly leave a space between the powder and the wadd, because then not only the powder explodes with uncommon violence, but the air also in the vacant space suddenly expands with the heat and the barrel of the piece is burst, and the fragments are, like so many balls, discharged in all directions. And what desolation has been caused in the midst of cities by powder wagons, when the axles have become heated by friction and the powder thereby ignited. How often has the magazine of a man of war caused destruction far and wide, or as in Leyden, the destruction of a whole city-quarter!

Saltpetre, especially in hot countries, is diffused in such abundance, its use from the early times has been so manifold, the occasions on which it comes into contact and mixture with carbon are so often occurring that the observation of its effects when inflamed in connection with carbon, lay close at hand to the ancients. We may readily concede to the student of Asiatic history that the Chinese were acquainted with the composition and effect of gunpowder long before the nations of Europe, and that this knowledge passed from China to other nations of the east. Many an alchemist and fire-worker of the middle ages in one country or another, as the Greek Marcus in the 9th century, the Englishman Roger Bacon, and the German Albert the great, and his countryman, the well-known Berthold Schwarz, in the 13th century, have fallen upon the discovery of the combustible material which burns with the violence and with the crashing sound of thunder, and which, according to *Roger Bacon's* assertion, had the power to destroy cities and

armies. The miners in Rammelsberg, at Gosslar, employed gunpowder in the 12th century to blow up rocks, and by the same means the Count palatine Henry, son of Henry the Lion, in the year 1200, destroyed the walls of a strong castle at Tyre, in the war of the Crusades. For centuries, nations have had the suddenly released elasticity which dwells in gunpowder for their friend and foe, without obtaining such a mastery of it as to use it as a faithful servant. This strange power may be compared to a lion, driven in among the hostile ranks of an army, spreading terror and destruction, but afterwards turning its untamed fury upon those who drove him forth; while the tamed hound, watchful of the voice of his master, now opens upon the enemy or the game, and then, at the word of command, crouches at rest on the ground.

Another body, not first formed by Art, but everywhere to be had without trouble in the greatest abundance, is vastly better fitted to subserve human purposes by the expansive power of its vapor, and that is, water. We have already spoken of this element with its motherly nourishment, and of the substances into which it may be decomposed, and out of which it may be formed. But it will be well to notice here some of the remarkable properties, by which this elemental fluid is distinguished from most other bodies.

We know water in three different forms: in the solid form of ice or snow, in the common liquid form, and in that of gas or steam. When water passes from its ordinary state, in which it is cognizable to the eye, the palate and the hand, into that of gas, it withdraws itself, like a spirit, which has taken leave of the decaying body, from the notice of our senses. Water, in its purely gaseous state, is no longer visible to the eye, no longer sensible to the touch; it has retired from the circle of coarse material existences, and only returns within this circle when, *condensed as vapor*, it again takes a liquid state.

The fluid state of water, like that of mercury, is maintained only by a certain degree of heat. When the due heat is wanting, both these fluids pass into a solid form. To melt mercury a temperature is required, which feels to us as an almost insupportable cold, and at which land and water become stiff with snow and ice. To melt water there is needed a heat which is about 31° R., 72° F. higher than the melting point of mercury. Sulphur requires four times the heat; and to melt most of the metals, the heat must be increased many hundred and even thousand times. These last named bodies, when they pass into a fluid state, occupy, very generally, a larger space than when solid. In solidifying, on the other hand, they contract more or less perceptibly. Consequently they become at the same time denser and heavier; the solid metal sinks in the melted to the bottom, because the latter is lighter.

Quite otherwise is the case in this respect with water. Water, when frozen, is greater in volume than when fluid: By its expansion, when freezing, it splits rocks and trees, as in the winter of 1709. At the same time it is also lighter. The ice does not by greater weight sink in the water that remains fluid, but is formed upon the surface, as a light covering, which becomes gradually thicker only by accessions from below. This remarkable element has its greatest density and weight, when it is cooled to 8° F. above the freezing point. It may be cooled to 8° below the freezing point without congealing, but as soon as it begins to become solid, so much heat is developed that the surrounding temperature rises.

Very noteworthy are the consequences of this peculiarity with which infinite wisdom has endowed the primal element of water. If, in freezing, water became denser and heavier, like other fusible bodies, and the ice sank on this account, as it was *formed in* water, to the bottom of our seas, then would these *collections* of water freeze throughout from below, and become

glacier-like masses, even in the more temperate countries, and fill the whole space occupied by water. When the warm season returned, the ice would hardly melt at the bottom, because the influence of the sun, penetrating through the water, the deeper it goes, must grow weaker. But even if a shallow lake could be melted through and through by the sun's heat, it would lose much of its interest for us, for no fish could live in it. The fish would have been frozen to death. But as it is, the upper layer of the water, when cooled by the winter air to 8° above the ice-point, sinks, as the heavier layer, to the bottom; it is followed by a second, and a third, and so on, until about the same degree of cold is communicated to the whole, and now the formation of the ice-covering begins, which affords a good protection against the cold air, while the average temperature of the bottom, which, in the temperate zone, is about 18° to 26° above the freezing point, communicates to the water from below, that degree of warmth, necessary to the life of the animal population of the water.

In the ocean, where the depth of the water is many times greater than in our lakes, the life and activity of the inhabitants of the sea is assisted by another property of water, by the fact that its elasticity, in its ordinary fluid state, is throughout very slight. The elasticity of atmospheric air is the cause of the perceptibly increasing density of the several strata of air from above downwards. Could we dig a shaft which should extend 32 miles below the surface of the earth, the air at that depth, on account of the pressure of the immense column of air resting on it, would have the density of water. At the depth of 51 miles, so it has been calculated, the air would be as dense as platinum. If water were as elastic as air, its density at the average depth of the ocean, would be so great that a stone would scarcely sink in it, but remain resting in it like a grain of *hempseed in honey; fishes*, even the strongest, would move

through it with more difficulty than a water rat through thick slime and mud, and at a certain depth would be unable to work through the floods, standing like solid walls. As it is, on the contrary, water, by virtue of its slight elasticity, is as easily penetrable above as near the surface by the animals that live in it; at the same time all bodies are affected by a greater pressure due to the increased weight of the column of water.

The properties which announce themselves in water in its third state, as a gas, when, like a spirit that has left the body, it is withdrawn from the sphere of our senses, and of the coarse corporeal world, are for us here, in the consideration of the power of heat, the most important. When nitric acid, in many of its chemical combinations, undergoes a gradual decomposition, whereby the nitrogen is set free, no explosion takes place, as in the case of gunpowder. The gaseous steam also, which is gradually formed in the evaporation of water, effects no perceptible change on surrounding objects. But as a stone, so long as it lies in the hand, is scarcely felt, but when discharged from a gun, receives a power, by which it may shatter not only the hand, but the whole arm of a man, so, by the rapidity, with which it is developed at the boiling point, steam has communicated to it a force like that of gunpowder, raising heavy burthens and bursting the sides of the vessel by which its expansion is obstructed. But the great elasticity manifested in steam thus suddenly generated, may be immediately controlled by the will of man; a proportionably slight and sudden cooling produces a return of the gaseous substance to the form of liquid water. The steam, rising from a pot of boiling water, when it ascends into the cold wintry air, is converted before our eyes into a watery cloud, or into water running together in drops. When, therefore, into a vessel, filled with steam, a small quantity of cold water is allowed to pass, the steam immediately yields up its elastic power, and returns obsequiously into the

harmless state of repose, from which it came. By this simple means, and by the exercise of some care, steam, like a huge, tamed elephant, may be led and used for the service of man.

Water, converted into steam at the boiling point, expands to 1700 times the volume of the water at a moderate temperature, and the elasticity of the steam increases, in a closed vessel, with an increase of heat. The elasticity of water, when suddenly converted by heat into steam, exceeds that of burning gunpowder, for by the steam produced from a pound of water a weight of 550 lbs. can be raised, while the explosion of a pound of gunpowder will scarcely raise a weight of 229 lbs.* As the tame elephant, when seized with frenzy, disregards the faint resistance of man, tearing down his huts, and breaking into whole crowds of human beings with his destructive strength, so oftentimes has steam, when not kept in careful subjection, laid buildings in ruins and destroyed numbers of men.

The difference between the motions caused by vital force and those produced by mere mechanical means, lies especially in this, that the latter immediately cease when the mechanical cause by which it is produced ceases to act, while the former are always again renewed, by the alternation of the condition of fulness at one point with the condition of want at another point, polarically opposite. The two vessels at the fountain of life,—the right and left ventricles of the heart and their auricles, stand in regard to their motions in such a regular relation to one another, that when the ventricle contracts its walls and empties itself, the auricle opens, and when the left ventricle drives out the blood, received from the lungs through its auricle, through the arteries into all parts of the body, then at the same time the right ventricle opens to receive the blood which flows towards it through its auricle from the veins. While one of

* *A cubic inch of water, converted into steam, will raise a ton a foot high.*

these cavities is emptying itself of the supply of its fluid contents, the other receives it; now here and now there the attraction becomes a repulsion, and the reverse.

This self-renewing alternation between attraction and repulsion, receiving and giving, is immediately obvious in animated beings in comparison with inanimate, unorganised bodies. The animal not only inhales, but exhales also; carbon, so to speak, also inhales the oxygen, while it is burning, and becomes carbonic acid, but it cannot again expel by its own power, the gas which it has taken in, it cannot, if, before being burnt it was a diamond, again take the form of a diamond, and so alternately become carbonic acid, and again diamond. When the caustic lime produced from the metal calcium is saturated with carbonic acid, and has then become solid limestone or marble, it cannot again by its own force give up this nutriment that it has taken, otherwise it would be a serious matter for the solidity of our mountains and the permanency of their forms and outlines. Only an external force, as the presence of a stronger acid, or a higher degree of heat, increasing the expansive power of the carbonic acid so that it may take the form of a gas, can terminate the solid combination, and deprive the lime of the substance with which perhaps it has been saturated for many thousands of years.

To refer again to the last mentioned process, familiar from the earliest times in the burning of lime for the preparation of mortar. The preponderance, which the increasing elasticity in the carbonic acid, obtains over the attraction by which it coheres to its earthly substance, is the reason of its development, the cause of that change by which the attraction at once becomes repulsion. When we consider somewhat more clearly the vital processes in the interior of an animated living body, it is clear that the succession of these processes rests upon now

an increase, and then a decrease of the elastic force of the organised structure, upon a change of the peculiar activity at one moment latent and at the next developed, upon the alternation of a pressure, as it were, from without, and a counter-pressure from within. The atmosphere resting on the surface of the human body, is, in relation to the whole body, an external pressure, acting upon it and defining its form. Again, in relation to the nerves, all the other parts of the body form an external pressure, and in relation to the soul or living principle, the brain and nervous system constitute another external force. While, in the processes of digestion, of the preparation of blood, of the formation of different parts, the vital power is given up to a union with matter, external and opposite to it, it appears, as it were, latent, and suppressed by the counter weight of the external substance; when, on the other hand, instead of supply, there comes demand, instead of rest, a striving, when the vital principle turns away, in a manner, from what has become old to the forming of the new, then it is awakened again to free activity. To the carbonic acid in limestone we give again its elasticity by the heat of our lime-kilns, what in this instance is effected by heat, in the living body is accomplished by the soul or principle of life.

The contrivance and working of our steam-engines imitate in a manner the processes of life, the continual alternation between pressure and counter-pressure, between the activity and the repose of elasticity. In a steam-engine of that construction, which alone was formerly used, the steam, evolved from the water of a boiler, passes into a metal cylinder, and there, by its elastic force, raises a closely fitting piston, until at a certain point, as it rises, the piston moves a piece of mechanism by which the valve of the tube by which the steam enters is closed, and at the same time the cock of a tube is turned, from which a stream of cold water is poured into the

cylinder. The cold water converts the steam into water, and a vacuum is produced into which the pressure of the atmosphere drives down the piston, until, in its descent, an entrance is again opened to the steam into the cylinder, and the piston is again raised by the power of the steam. Thus the pressure of the atmosphere and the counter-pressure of the steam act alternately, and, by the rising and falling of the piston, the various machinery is set in motion which serves to lift the heaviest weights or to keep in motion the paddles of steamboats or the wheels of locomotives.

A later and very valuable improvement in the construction of steam-engines does away with the pressure of the atmosphere, causing the piston to fall and to rise in the cylinder closed at the top by the force of the steam, which is admitted first into the upper and then into the lower part of the cylinder, and then let out of that part of the cylinder, in which it has duly exerted its force on the piston, into a reservoir (the so-called condenser,) which is surrounded with cold water, the low temperature of which instantly takes from the steam its gaseous form, and converts it again into water. By thus letting off the steam into a cool place, there is produced in the cylinder, first below and then above the piston, the vacuum, without which the falling and rising of the piston would not be possible. By this contrivance, by which both the pressure and the counter-pressure are produced entirely by the steam, a moving power can be applied to machinery, which at one time is less than that of the atmospheric pressure, and at another, the power can be increased, by an increase of heat, to a degree many times greater than the external pressure. This increased elasticity (high pressure) is used especially for locomotives.

In our days and in our regions, wherein hardly a country is found in which, in the space of a few miles, a steam-engine cannot be seen serving some purpose of human industry, or connected

with rail-road trains, either fixed to one spot, or from time to time, a coming or a parting guest, it is as unnecessary to describe minutely the structure and particular parts of this valuable machine, as the construction of a water-mill. We all know that the water in the boiler is heated, not directly by the fire under the boiler, but by metal tubes inside the boiler, through which the hot air passes, by which arrangement, a much greater extent of hot surface is presented to the water. We have all heard the snorting of the air as it is exhaled and inhaled—we have all seen the volume of smoke, which gives to the swift locomotive or steamboat, in the eye of uncivilized nations or of children, the appearing of a wild animal, and puts to flight the cattle in whose neighborhood the spectacle passes, filling them with terror.

To the English, (and to the descendants of Englishmen,) the masters in mechanical inventions and arts, belongs, before all, the merit of inventing and perfecting the steam-engine, and applying it to its manifold uses. Once and again some idea of the application of steam to purposes of human labor may have been naturally suggested by the description given by *Hero of Alexandria* (120 years B. C.) of a metal ball, filled with steam, which, by the force of the vapor issuing from a small tube, was made to revolve on its axis. The first, certain vestige, however, of the application of steam to the raising of a stream of water 40 feet high, we find in 1655, in the work of an Englishman, the *Marquis of Worcester*. Another Englishman, Sir *Samuel Moreland*, it was, who, in 1683, proposed to Louis XIV., a very well contrived plan, by which water could be raised from a great depth by means of steam. Fifteen years afterwards, (1698,) the English captain, *Savary*, obtained a patent for his invention of a steam-engine to pump water. The whole contrivance consisted in conducting steam into a pipe (the *chamber of the pump*,) and then, by cooling the pipe and

condensing the steam a vacuum was generated, into which th water rose. An English handicraftsman, the smith *Neucomen*, in 1705, taught the way of condensing the steam, and of causing the piston to descend by the pressure of the atmospheric air in a shorter time by throwing in water. In 1720, the German *Leupold*, to whom the science of mechanics owes much, made known his plan for a more effective application of steam; mechanics of later times have found much that is useful in his methods. Still, however, the use of steam-engines remained limited to a few purposes; except that they rendered service here and there in drawing off water from mines, they were employed almost entirely by the opulent in the construction of artificial fountains.

The Scotchman, *James Watt*, opened the way to the general and easy use of this important invention. From his factory, established in 1769, in partnership with the machinist, *Matthew Bolton*, steam-engines of regular construction were sent forth, with which all parts of Europe were provided. He it was, who showed how to avoid the direct introduction of cold water into the cylinder by leading off the steam into the condenser mentioned above. Previously, by the elasticity of steam, only the rise of the piston was effected, and accordingly the machine was irregular in its motion. By his invention, already referred to, *Watt* made such movements possible as require a steadily acting power.

There was now only one step wanting to the invention of the steamboat, and yet another to the invention of the steam car. For the first, we are indebted to *Robert Fulton*, by birth a Pennsylvanian, who first, as a goldsmith's apprentice in Philadelphia, won reputation as a good draftsman. Trusting too much to his talent in this department, he betook himself to London, in order to become a great painter in the school of the celebrated West. But the excellent American draftsman was

not capable of shining as a painter in England. Of this he became aware, and gave himself to mechanics, and, in company with *Ramsey*, who was engaged in this employment, to the making of steam-engines, destined for Virginia. While thus occupied, he conceived the thought of applying the steam-engine to vessels on the water. With scanty means, he ventured upon the carrying out of this idea. His experiments, however, in France and England, attracted no great attention. Twelve years long the genius of the man struggled with the obstacles, which the want of pecuniary means laid in the way of executing his ingenious and well-considered contrivances. Finally, in 1807, he got so far as to be able to build in New York a steamboat of 160 tons, moved by a 20 horse power engine, and which went up the Hudson, from New York to Albany, a distance of 150 miles, in two and thirty hours. The success of this enterprise dissipated in the minds of Fulton's countrymen the distrust occasioned by the unfortunate experiment made in 1788 by the watchmaker, *Fitch*, in Philadelphia, the boiler of whose steamboat burst at the first trial. But Fulton, the author of a new and signal era in navigation, received no outward compensation for his great invention. He received, it is true, from the United States, a patent, securing to him the right of steamboat navigation on the Hudson river; but he was deprived of this right, the grant being adjudged unconstitutional, and he suffered the vexation of having the glory and advantage of the first invention made a matter of dispute. He died in 1815, at the age of 48; he did not live to see the entire completion of his plan of building a large steam frigate. Many others have been made rich by means of his invention, as steamboats soon began to be built in all the countries of Europe, in accordance with his plan. He himself was not able to cancel the weight of debt incurred in the necessary expense of his grand undertaking.

What services steam navigation has rendered to the intercourse of nations, is now apparent to all. Vasco de Gama's renowned enterprise of sailing from Europe to the East Indies, has indeed been accomplished by thousands, since he led the way. Nevertheless, the voyage to the East Indies, apart from the ordinary perils of the sea, is most tedious and difficult; now the English steamboats pass to the Egyptian coast, then through the Red Sea and the Indian Ocean to the East Indies, in from 5 to 6 weeks, while sailing ships formerly reached the same goal scarcely in as many months. By their steamboats, Europeans, vastly more effectually than in former times, have become the rulers of the seas, and the protectors of sea-coasts against the murderous ravages of sea-robbers. How difficult it was formerly to overtake the Malay or Chinese pirates in their junks, when, before the very eyes of Europeans, they had set fire to cities and villages on the coasts of the Philippines, murdering their harmless inhabitants, or when their hordes had seized a European merchantman, destroyed her crew, and plundered her cargo. Now these robbers fear the steamboats of the Europeans as much as the swift-footed hare fears the swifter-winged eagle; and soon all seas traversed by steamboasts will be cleared of pirates, and the inhabitants of their borders be secure against their murderous attacks.

A similar revolution in the intercourse of cities and nations, has been effected by the invention of the steam carriage. It was brought to its present state of completeness, and into general use, at a somewhat later period than the steamboat, although in 1759, an Englishman, *Robinson*, communicated to James Watt, whom we have already mentioned as the famous maker of steam-engines, a plan for the construction of steam carriages. But he commanded little attention, and the experiments made by him and others either wholly failed, or disappointed

expectation. Besides, the invention of steam carriages, if it were to be successful, required another, much older invention, that of rail-roads; for our ordinary roads, are not suited to such vehicles. And here England possessed great advantages. Although the use of level wooden roads with fixed tracks for the conveyance of heavy burdens, had been originally introduced into England by the German miners, (whom Queen Elizabeth called into the country,) and had been confined only to the mines, yet the foundation for the present rail-roads was laid in England in 1776, when *Curr* placed plates, or rails of iron over the wood, and in 1797, when *Barns*, instead of wood, in many countries so dear and difficult to be had, employed stone on which the iron rails were laid. Since 1825, iron roads of this description were to be found, first in England, then in France, Austria, and America. These roads were used to facilitate the transportation of goods to and from various centres of trade. Upon a road of this character, the first steam carriage of complete construction, made by *Stephenson* in 1829, obtained the prize of 6000 guilders ($2400,) which was offered for this new method of transportation. Stephenson's locomotive carried 250 cwt. at a rate of eleven miles an hour; a speed which is far excelled by the more perfect locomotives of the present day, which run at a rate of double and even more than treble the velocity of the first experiment.

In order to generate steam rapidly, the boiler of the locomotive engine is constructed with tubes of copper or iron passing through it, and through which tubes the hot air and flame passes to the chimney. The boiler is supplied with the necessary water by a contrivance, which is kept in action by the machine itself. The steam, formed by contact of the water with the numerous tubes, exposed to the heat, collects in the steam chest, and thence sets the pistons of two cylinders in motion, which motion is communicated to the wheels. Economy of

space and weight is a special consideration in the locomotive. On this account the high pressure engine has necessarily been applied, by which great power is obtained within a small space. The steam, however, when used, is let off into the air instead of being conducted into a heavy condenser.

The increase of steam-transportation on rail-roads has been immense. In England rail-roads run in all directions, over an extent in all of about 2200 English miles, and in the United States of America, the length of all the rail-roads, taken together, is double that amount.* In Germany the first rail-road was made in 1835, from Nuremburg to Fürth. Now almost all parts of Germany share in the advantages of the great invention.

We may mention here, in passing, the so-called atmospheric rail-road on which the locomotive is impelled, not by steam but by atmospheric pressure. Otto von Guerike, the inventor of the air-pump, excited the wonder of the spectators at the imperial diet at Regensburg by that experiment, by which a close-fitting piston in a cylinder, from which the air had been pumped, was, by the pressure of the air, raised with such power, that a number of strong men attempted in vain to hold it down. As the force of the pressure of the air amounts to about 2000 lbs. to every square foot, a piston of 1½ feet surface, must be raised in a cylinder, exhausted of air, with such force as to carry with it a weight of 3000 lbs. In Ireland, between Dalkey and Kingstown, the first successful experiment of a rail-road about 4 miles long, upon the principle of atmospheric pressure, has been made by *Clegg* and others. Between the Wils of the road lies a cast iron cylinder 9200 feet in length, of ste. ages. Bu made by

* be said of rail-roads in this country and elsewhere, as Burke said lation of the American Colonies. If we estimate their number while the calculation is going on, the exaggeration ceases. The rail-roads in this country is nearly 7000 miles.

closed with valves at the ends, connected by a suction tube, with an air-pump over 5 feet in diameter, which is set in motion to exhaust the air from the cylinder by a steam engine of a hundred horse power. In 6 or 8 minutes, the exhaustion of the air in the cylinder, which is 15 inches in diameter inside, is so far effected, that when the air is let in behind a piston, moving in this cylinder, the piston is driven by a force capable of carrying a weight of more than 2000 lbs. connected with it, with the speed of more than a league a minute. The flat shaped rod of the piston runs in an opening made in the upper part of the cylinder through its whole length; this opening, which is covered with a lid or valve of leather and sheet iron, is opened and closed by a contrivance attached to the piston. Although this short atmospheric rail-road renders good service at the place, being used for the conveyance of stone for the construction of a harbor, there are yet such serious objections to an imitation of the same on a large scale, that it has never been undertaken.

Heat, therefore, remains the sole generator of steam for our locomotives, and it is heat alone that renders possible the exhaustion of the air required in the atmospheric rail-road. What is the uncertain speed of balloons, even under the most favorable circumstances in comparison with the swiftness of our locomotives, which already in several places accomplish a league in 4 minutes, 15 leagues in an hour. Could we travel at such a speed without interruption for 30 days, we should pass over an extent equal to the circumference of the earth. A journey which formerly took days, has now become equivalent to a walk of a few hours. One friend invites another living some 50 miles off to dine with him, and the invited guest attends to his daily affairs, arrives at the right time, dines, and sleeps the same night under his own roof. The number of travelers upon *the rail-roads of England*, leaving out of account the

baggage and goods carried with them, amounts annually to some 20 millions. Whole masses of goods and human beings, previously in a state of repose, have been thrown by steam into lively and ever-renewed activity. Grey old men, who, devoted to their several avocations, had bidden farewell forever to the friends and companions of their youth, on account of the great distance at which they lived, have now, not once, but often, renewed their early associations; space no longer produces separation.

When we consider all the services rendered by steam, since, by the invention of steam-engines, this powerful agent was made the servant of man, we perceive especially how important is the saving which is made of human power. The power of a steam-engine is ordinarily estimated by the weight of water which it is able to raise in a certain time. If it raises 550 lbs. a foot high in a second, it accomplishes as much as one horse. If it raises a double, treble, or four-fold weight, the same height in the same time, it does the work of 2, 3 or 4 horses, and the same may be said of it when it raises 550 lbs. in ½, ⅓, ¼ of a second a foot high. It may be stated on an average that about five men are equal in power to one horse. Hence it may be estimated that the steam-engines in England in 1833, achieved as much labor as 2½ millions of horses or 12½ millions of men; in France the steam-engines there employed in that year, performed the work of 1,785,500 horses, consequently of more than 8 millions of men. In Prussia steam supplied the labor of 915,000, or of more than 4½ millions of men.

From some passages in the writings of antiquity, it has been supposed that the Egyptians were not only acquainted with the moving power of steam, but also applied it to various purposes. Were this the fact, and if they had command of the power *which we have* possessed since the introduction of steam-en-

gines, they would not have been compelled, in building their huge pyramid not far from Ghizeh, to employ 100,000 men for a space of 20 years, for it has been reckoned that this giant structure, estimated to weigh 186 millions of cwt., might, by means of steam-engines under the management and with the aid of 36,000 men, be moved from the place where it stands and set up on another spot in the space of 18 hours. But we do not now apply the powers gained by art, to the building of pyramids, like the Egyptians, who lived on onions and lentils (beans,) but, rather to the preparation of the means of getting tea, coffee, and sugar.

The excellence of the construction of a steam-engine is determined, not merely by the force it exerts, but also by the greater or less expense of means required to generate the power. To produce steam enough in an engine of Watt's construction, which was used in America in 1811, there was required, to obtain power sufficient to raise 15 millions pounds of water, a bushel of coals per minute. By subsequent improvements the consumption of coal in 1815, was reduced to not much over ⅔ds of that quantity; and a high-pressure engine, built upon the plan of *Woolf*, with the same means, possessed three times the power. In England also, since recent improvements have been made in the steam-engine, only ⅔ds, and indeed only half the fuel is used, that was required in the best works of the kind thirty years ago. But as great as this expense may be, together with the interest of the original outlay, and costly as may be the construction of railroads (under the most favorable circumstances, $240,000 per mile (German,) about 4½ English miles, in less favorable, several millions of dollars) still the profits, which steam-enginery produces to the capitalist, and the increase it has given to the activity of trade, are every way greater.

We have thus considered an effect of heat which has become serviceable in our times to an eminent degree. We return, however, from the effect to the cause, and going a few steps further, we will take a view of the most common means, by which, with or without our agency, heat is generated in our material world.

33. THE GENERATION OF HEAT IN THE COMBUSTION OF BODIES.

To kindle a fire, two material opposites are necessary, of which one is styled the supporter of combustion, the other, the combustible substance. In our wood and coal fires, the carbon and the hydrogen, for the most part, combined with it, form the combustible substance, the oxygen of the atmosphere, the kindling material, or supporter of combustion. In some cases one and the same body fills both offices. Thus, when red hot copper is burnt in sulphur vapor, sulphur is the supporter of combustion, and the copper the combustible; and in such combinations of sulphur with metals, the same phenomena of fire are presented, as in the ordinary process of burning in atmospheric air. But the same substance, sulphur, when it burns in the usual way, and of course combines with oxygen, acts the part of a combustible, and leaves to the oxygen gas the office of supporting the combustion.

In considering steam we observed that there is a great difference between the effect of this agent when gradually formed, and when more quickly generated by heat; the application of high-pressure teaches that the elasticity of steam can be greatly increased by an increased degree of the heat used to generate steam. It is not the motion alone, but the rapidity of the same, that determines the measure of its effect.

What we have said of the activity of steam generated in different ways, and what is taught us by every hurricane, when the same mass of air, whose pressure, while resting upon and around us, we scarcely remark, uproots trees in its swift motion and prostrates houses, is true also of the process of combustion, or of the combination of a combustible body with oxygen. Dry wood, split into small pieces, instantly catches fire upon the approach of a flame, and we then have the phenomena of complete combustion, light and heat. The carbon of the wood, in combination with the atmospheric oxygen, is converted into carbonic acid, the hydrogen into watery vapor, which, upon being cooled, takes a liquid state. When the burning of the dry pieces of wood takes place in a closed vessel, and when the oxygen is wholly or in great part taken up in the formation of the carbonic acid, then a burning shaving is extinguished, if it is held in the vessel, for the carbonic acid gas can neither support combustion, or the breathing of an animal. The case is the same also, when we put a burning shaving into the air contained in a closed vessel, in which there is wet saw-dust, or damp wood. After a few hours, the oxygen of the atmosphere, has entered into combination with the carbon of the wet wood, just as if we had burnt the dry wood in the vessel; the burning shaving goes out as quickly as if we had dipt it into water. The light of the sun undoubtedly exerts a disturbing influence on the process of this slow combustion or decay, as appears in the bleaching of linen, in which a combination of oxygen spontaneously takes place with the easily decomposible particles of the vegetable texture, or with those other substances of an organic nature, which, by the free disengagement of carbon, discolor the material. Although the influence of sunlight promotes, in bleaching, and other similar processes, a slow combustion or decay, just as the flame

of a candle produces a speedy combustion, yet it is necessary that the linen be damp.

That that gradual combination of the combustible with the supporter of combustion, which takes place especially in the decay of organized bodies, cannot properly be called combustion, is intelligible to every child. The beginning and continuance of combustion depends, as we see upon our hearths, upon a degree of heat, which water, sprinkled upon the fire, or the dampness of the burning wood reduces, inasmuch as the evaporation of the water goes on at the expense of the heat. We have already noted it as the chief effect of heat that it destroys the cohesion of the particles of bodies. The commencing dissolution of that cohesion announces itself in the increased expansion of bodies, in their further progress in becoming fluid (melting,) or in their evaporation.

In the case of those solid bodies, which have been pulverised in the finest possible manner by mechanical means, the natural historian has made a remarkable observation. When these minute particles, invisible to the naked eye, are placed, floating on a drop of oil or water, under a microscope, a motion among them, to and from one another, is apparent, which cannot be explained by the evaporation of the fluid. For it is grounded upon a polaric attraction and repulsion, upon a mutual revolution of one around another, by which it greatly resembles the motion of little microscopic animals. With the dissolution of the cohesion of bodies, even by mechanical force, the particles of the same become capable of a mutual motion based upon the universal cause of all motion, polaric opposition.

The combustion of bodies consist in a lively motion, one towards another, of the particles of the combustible and supporting substances, in a motion which is communicated to our *senses as* light and as heat, and, in this form, acts upon sur-

rounding objects. When platinum is separated from a fluid in which it has been chemically dissolved, then its finely pulverised particles no longer show a metallic brightness, but appear as a black powder. When it is dried and exposed to the air, it attracts oxygen so powerfully that it takes up 252 times its volume. The attraction of the metal for oxygen, is excited without producing an actual combustion. But when hydrogen is allowed to pass over platinum powder, thus filled with 252 fold of condensed oxygen, the metal begins to glow, for now a combustion of hydrogen arises which diffuses its heat through the whole finely pulverised mass; water is formed. This process can be recalled at pleasure, for whenever the stream of inflammable air is checked, and thereby the combustion is checked also, the platinum powder again takes up oxygen, and may be ignited by a new stream of hydrogen. The same property observable in the above mentioned metallic powder, is found also in the so-called spongy platinum, which is obtained by heating chloroplatinate of ammonia, and the easy ignition of an artificially prepared powder, shows us what means of promoting combustion are offered by the pulverising of bodies, by the destruction of the cohesion of their substances.

As we promote rapid combustion with flame, so also we may promote gradual combustion, that is, the combination of fermenting fluids with the oxygen of the air, and their conversion thus into vinegar by mechanical means, by causing the fermenting fluid to spread as much surface as possible to the contact of the air. Formerly, when vinegar was to be made out of the dregs of beer, or out of bad wine, or brandy, or other similar fluids, the liquor was partially exposed to the air in casks, and it took weeks or months to complete the process. Now vinegar can be made out of brandy in the course of a single day, by allowing the brandy, diluted with water, to trickle through casks filled with shavings, through the loose layers of which the air

from without may pass gently. The surface of the fermenting fluid is, by this process, spread more than a thousand fold, its parts, previously near each other, are separated, their cohesion is destroyed, but only in a mechanical way, it is true; a somewhat similar effect, however, is produced, as by the dissolution of the cohesion of the parts of a combustible body by heat.

Even in those mixtures which kindle spontaneously, as soon as they are exposed to the air or to oxygen, of which sort is that which is made by triturating together 8 parts in weight of red lead, (peroxyde of lead,) and $2\frac{1}{2}$ parts of tartaric acid, free from water; by pulverising the mass, inflammability may be promoted; and in fact, we avail ourselves with the same result of the mechanical process of pulverising in the manufacture of gunpowder. Here also come those cases, in which, without even a strong mechanical pressure powdered coal has spontaneously ignited to the fatal injury of houses and whole cities.

As a single spark kindles gunpowder, so the burning of one combustible body is communicated to another; from every burning part that heat radiates, which tends to destroy the cohesion of the adjoining parts, and consequently to prepare them for the state of combustion.

Although, as we said, the fermentation of substances, whereby they attract oxygen much more slowly than in the process of combustion, can only in an indirect sense be called combustion, yet it is interesting to remark an agreement that exists between these two processes. Just as, in burning, the flame with its intense heat spreads from one point of the ignited mass to another, so is it also in the fermentation of organic bodies susceptible of this kind of decomposition. In most of these bodies a strong disposition to combine with oxygen appears, even at an ordinary temperature, directly that they come in contact with a fermenting or decaying substance. In order to *ignite hydrogen*, to effect its combination with oxygen and pro-

duce water, with the phenomena of light and heat, there is required a degree of heat of 240° R., 540° F., (300° Celsius.) When, at the usual temperature of the air, a mixture of oxygen and hydrogen is kept in a bottle or any other well closed vessel, both maintain their pure state, until the heat of a flame, with which they come in contact, or the electric spark, effects their union, (ignition.) When, on the other hand, in a bottle filled with atmospheric air, and a mixture of hydrogen, a linen bag is suspended, containing damp saw-dust, bark, mouldy earth, or any other substances, susceptible of a sort of fermenting decay, then the decay proceeds just as in the open air. The oxygen of the surrounding air is partly converted into carbonic acid, but at the same time, the hydrogen also takes part in the process of decay, it combines, as in combustion, with the oxygen, and water is the result. In precisely the same way, and for the same reason, the vapor of spirits of wine also, in a space, in which rotting wood or other decaying substances are contained, enters into union with the oxygen, the last product of which is acetic acid, or acid of vinegar.

Although in the fermentation and in the decay of bodies, disposed thereto, especially when in large masses, an increase of heat is observable, yet this heat, affecting our feelings and our thermometers, is by no means that which exerts the principal influence in the transmission of fermentation or decay from one body to another. In the cool weather of our damp autumn days, a decaying apple communicates decay to other apples in which it comes in contact, and the decay spreads rapidly, according to the quantity of fruit heaped together. In vaults also, at a low temperature, decay takes its course. Still external heat operates to hasten these processes, by which inflammable substances are combined with oxygen, but at the same time other changes occur also.

Even the different appearances or states of combustion, properly so called, depend upon the degree of heat which exists. The slow extinguishing of a combustible body goes on of itself under a mere red heat; complete combustion with a clear flame is connected with a white heat. When a platinum wire, spirally wound, or a glass ball covered with platinum, is fastened over the wick of a spirit-lamp, and the lamp is allowed to burn until the platinum has become red hot, and is then extinguished, the spirits continue slowly burning, not indeed that it emits any clear flame, but the platinum shows in the dark a red heat, until the spirits of wine is all consumed.

Accordingly as combustible bodies require a greater or less heat for their ignition, the continuance of their combustion, in the same circumstances, is greater or less. When a wax taper, a stream of hydrogen, a piece of sulphur, and a piece of phosphorus, are ignited in a closed vessel, filled with common air, in the gradual decrease of the oxygen the taper first goes out, then the hydrogen, next the sulphur, and at last the phosphorus. Phosphorus requires, for its ignition a heat of only 108° F. Sulphur 527°; hydrogen 560°. Phosphorus, cased over with lamp-black, will ignite at an ordinary temperature, and like the platinum mentioned above, will also show a slow process of combustion.

The force of the attraction, subsisting between a combustible body and oxygen, is affected by the proportions in which the two substances are present. As combustible bodies require, as already stated, their several degrees of heat for ignition, in like order they require, to support combustion, a proportionate supply of oxygen. Lighted tapers, set in the sun, burn weaker, not only in appearance, but in reality, because the light of the sun expands and rarefies the surrounding air. In the shade the combustible substace of a taper combines more copiously with

the oxygen of the air, and the flame becomes more lively, but the combustion is most perfect in a dark place, where both the combustible body and the supporter of combustion, are, at the same time, most fully consumed. When the mixture of hydrogen and oxygen, which is perfectly adapted to the formation of water—two parts in volume of hydrogen and one of oxygen—is rarefied about 18 fold, it cannot be ignited even by the electric spark, and when rarefied 8 fold, it is no longer susceptible of ordinary ignition. Phosphorus, on the other hand, when wrapt in cotton, or sprinkled with sulphur, with charcoal, saltpetre, or some metallic substance, ignites even more easily in rarefied, than in condensed air; it continues burning at a 63 fold rarefaction of the air.

The degree of heat, required by bodies, which are ignited with more difficulty, to maintain them in a state of combustion, is instantly reduced, when the oxygen is not supplied in sufficient quantities, and with a certain activity depending on the swiftness of its current. In order to burn stone-coal, it must be laid on a grate, and be exposed to a draught of air which must be directed towards, as well as under it; while wood, which is so easily ignited comparatively, burns readily on the open ground, because that draught is sufficient, which is produced by the ascent of the warm, and the rushing of the cold air, to supply itself. In atmospheric air, condensed 5 fold, a red hot iron wire, or steel spring burns as vividly as in pure oxygen, for as atmospheric air consists of 4 parts in weight of nitrogen and one of oxygen, the wire or steel has access, in air thus condensed, to just as much oxygen, as when, under the ordinary pressure of the air, it is supplied with pure oxygen.

The more or less sudden extinction of flame is a necessary consequence of all those circumstances, by which oxygen is cut off from the combustible body, or of the reduction of the heat by a *sudden cooling, and* a process of evaporation. As fire can

be prevented from spreading, by the sprinkling of water or earth, by the same means also a combustible body can be prevented from catching fire even when in contact with flame. By means of a dress, made of sheep's wool, which has been dipt in salt-water, (SALZ SOOLE,) over which a fine meshed network is drawn, a man may venture into a flame, without injury. Besides, a network of this sort has the remarkable property of impeding the communication of flame from one combustible to another. A lantern, surrounded with wire-work, and containing a lighted taper, may safely be placed in hay or straw; with the safety lamp of *Davy*—a small lantern of fine wire-work, like a sieve, having very small interstices, one may go into coal mines or vaults full of fermenting fluids, where explosive gas has formed, without fearing that the easily inflammable mixture of hydrogen and carbon will take fire from the taper in the lantern.

In the combustion of bodies, composed of several inflammable substances, that element first unites with the oxygen, which has the strongest disposition to this union, and for the reason, mentioned in ch. 16., only when the more inflammable substance is saturated with oxygen, does the less inflammable take fire. Thus when carburetted hydrogen is burned, the hydrogen first appropriates to itself from the surrounding air so much oxygen as is required to form with it water, and only when there is oxygen enough, does the carbon unite with it, and make carbonic acid gas, but if oxygen is not present in sufficient quantity, the carbon is separated unmixed. When also, in the combustion of a body, which contains carbon and hydrogen, the heat is not great enough, the carbon is separated, uncombined; from such a body, not thoroughly ignited, the carbon rises, in union with watery vapor, as smoke.

*The sen*sible diffusion of heat, in the combustion of bodies, *depends not* only on the character of the combustible substance,

and the quantity of oxygen taken up, but also upon the rapidity with which the combustion goes on. Generally, three times as much heat is obtained from one pound of charcoal, as from a pound of dry wood. A still greater heat is obtained from white wax and gaseous and fat oils, while spirits of wine is nearly equal to coal, in the heat given out. The light, which accompanies the heat produced by a burning body, is generally stronger in proportion to the quantity of olefiant gas contained in it. The weak light, given out by a hydrogen gas flame, is immediately increased by previously conducting the gas through the oil of turpentine, and thereby mixing it with the vapors of the same; the flame of our spirit lamps shines much stronger than usual when the cotton wick is steeped in carbonate or sulphate of soda, or when a little oil of turpentine is mixed with the spirits of wine. When a combustible body, like thoroughly charred wood, has a disposition to volatilize, it glows without flame; the wood throws off fugitive particles, and it therefore flames and glows at the same time.

What all these phenomena of Light and Heat, accompanying combustion, teach us concerning the peculiar nature of these two material forces—whether they are substances, but of a higher order, uniting with substances of a lower order, which are subject to the gravitating force of our planet, from which those two higher substances, under certain circumstances, become free, or whether they are only motions of material bodies, communicated from one substance to another, we will not here endeavor to decide. The answer to these questions appears to be connected with an understanding of the relation subsisting between the body and the soul. The soul indeed is not a body in the sense in which the flesh, the blood, and the bones are so, but its being and working proceed not from a mutual action of the flesh and blood, the bones and the skin, but it is a self-acting *existence, as, according to* its sphere, the body is also. The

consideration of Light and Heat offers to the mind a riddle, deeper and more comprehensive than ever Sphinx proposed.

34. THE PECULIAR HEAT OF LIVING ORGANISED BODIES.

We have already spoken of the heat of the living human body. But not only is heat generated and diffused by the processes of formation, and by the motion of the human body, but wherever a soul or living principle is fashioning and animating matter, to subserve the purposes of its activity, there is active, also, heat in a certain degree.

Many plants, such as water cresses, not only keep themselves unfrozen under the snow, but they form a hollow in the snow around them, and when the water in which they stand has become ice, that portion of the water nearest to these plants remains fluid. Precisely when the temperature of the air has reached its lowest point, there is found by the thermometer in the morning towards sunrise, a heat in the interior of trees greater than that of the average temperature of March; while at midday, when the evaporation is the greatest, the heat falls below the average degree of the month. During the processes of blossoming and of the first germination of the fruit, an increase of heat has been observed in several plants.

The source of vital heat is in animals, still more strikingly than in plants, similar to that which in combustion consists in a more or less rapid and active combination of combustible substances with oxygen. The animal needs for the support of life, not only food, but, above all, the inhalation of air, and indeed the more perfect the animal is, so much the more does it consume of oxygen, or vital air.

How warm it is even in winter, or in the cold spring and *autumn days* in a populous beehive, is known to every one *who keeps* bees. When in the open air the thermometer

stands only one degree above freezing, the heat in a beehive stands at 72° F; in spring, when the thermometer in the open air does not reach 54°, the heat in a beehive reaches 81°.

The increase of heat here and throughout the animal world, depends of course in a great measure on motion. When, in May or June, at the time of swarming, a universal excitement reigns among the population of the hive, the heat rises to such a degree that the cells of wax begin to melt. More striking, however, than the influence of motion is the influence of nutriment in developing animal heat. The temperature of a beehive falls, and a perceptible coolness takes place when the bees suffer a want of food, while the heat again rises when the hungry creatures, unable to procure sufficient nourishment of themselves, are supplied with abundant food. A similar remark made in reference to all insects living in the open air,—namely, that they possess a peculiar warmth, which increases or decreases with the increase or decrease of their food, leads us to a further conclusion as to the cause of this heat. The food upon which insects live, and all organised bodies, consist chiefly of combustible substances, particularly of carbon and hydrogen, which, together with the nitrogen and oxygen connected with them, enter into the juices and solid parts of the living body. The consumption of atmospheric oxygen by the breathing of insects is very considerable, and the need of it so urgent, that a bee dies of suffocation when all the air-passages lying on each side of its body are closed with varnish, or some similar substance, just like a warm blooded animal which is prevented from breathing. The product of the combination of the oxygen which is inhaled, with the carbon and hydrogen of the corporeal components of the animal body, is, as an examination of the exhaled air shows, carbonic acid gas and water, just as in combustion. The process of breathing admits of being regarded, *much more* than fermentation, as a species of

combustion, the invisible flame of which is indeed a source of sensible heat.

Wet wood, as we well know, burns much worse than dry, and, the quantity being the same, gives out much less heat, the reason of which is very plain; in the case of the wet wood much of the heat is consumed in converting the water into steam or vapor, and thereby a great reduction of the heat is produced. Fresh hewn wood contains 42, dry wood only 25 per cent. of water. A great part of the animals who live in water, and who breathe, not through lungs, but through gills, for a similar reason manifest only a small degree of animal heat, even when supplied with sufficient air and nourishment. The air inhaled by land animals is indeed never free from watery vapor, but it stands related to that which the fish draws into its gills with the water, and takes into the blood vessels, just as in combustion well dried wood is related to wet. But not only the presence of water in the air which they inhale, but also the slower and more imperfect course which the breath takes in fishes and amphibious animals, explains the low degree of animal heat which they show. Young alligators are able to live tolerably long without inconvenience, in nitrogen; and it is well known of other amphibious animals that they can live in air which is very deficient in oxygen, and incapable of sustaining life in the higher animals. The formation of carbonic acid is also in like measure very slight in amphibious and water animals, in comparison with mammalia, birds, and even insects. Nevertheless a certain, though very small amount of vital heat, is observable in fishes, amounting in the stomach of a trout taken from the wintry cold water of Slave Lake, to 4½° higher than that of the surrounding element, and in a white fish to 9°, and in the tunny-fish even to 18° above the external *temperature*. In the bodies of many thick-scaled snakes, a *heat is* perceptible exceeding that of the air one or more de-

grees; while on the other hand, in the case of amphibious animals devoid of hair, as of frogs for example, the great evaporation of the moisture of their bodies continually going on, causes a perceptible diminution of warmth, and thus their animal heat is often much below that of the atmosphere. A similar fact is found in the case of snails.

In respect of animals who breathe through lungs, it is apparent that their vital heat depends upon the quantity of oxygen, and the rapidity with which the carbon and hydrogen of their fluids combine with oxygen, to form carbonic acid and water. The more of these two substances is generated in breathing, so much the more does the degree of vital heat increase, which, on that account is greater by several degrees in birds, than in the mammalia. The latter, whose internal structure approaches nearest to that of man, possess also a blood-heat, very nearly as great as that of man, amounting generally from 97° F. to almost 104° F. That particular specimen of the armadillo, which showed a heat of only 86° F. was affected by the sickly condition in which it was. That the temperature of the human body, in comparison with that of other mammalia, is rather lower than higher, may perhaps be owing to the quality of the human skin, and the evaporation from the same. But that, in the most perfect of earthly forms, the human body, the peculiar internal heat is evolved by the process of breathing, appears from observations upon the sick. When, during a protracted fainting fit, or in catalepsy, the breathing is obstructed, then a deadly coldness seizes the limbs. The case is somewhat similar in regard to many warm blooded animals, who spend the winter in sleep, and whose breathing is very slow, or for a time wholly suspended. The warmth of an animal of this description sinks almost to the temperature of the season, and although perhaps an internal heat of 2° to 3° above that temperature may be observed, it is doubtful whether

it is the heat accompanying the vital process of formation and decomposition, or whether it arises merely from the mass of animal matter.

The process, just alluded to, of a continuous formation and decomposition going on, as long as life endures, in all parts of the body, is, substantially, nothing else than a breathing, for it depends throughout only upon a constant interchange and combination of carbon and hydrogen with oxygen.

The more exact observation of animal heat, of its origin, its increase, or its diminution, confirms a previous conjecture that this fire, which appears, not as a visible flame, but as a moving force upon the fire-place of life, is generated and maintained by the same law as that fire in the neighborhood of the naphtha springs, in which the Parsee, on the borders of the Caspian sea, sees a symbol of the creative power. The more oxygen a breathing animal takes up and applies to its physical formation and decomposition, the greater becomes its vital heat. But this animal heat is generated by the inhalation of air, not only in the lungs, but in all the parts and spaces of the body into which the blood can penetrate, which, combining with oxygen in the lungs, is collected in the left ventricle of the heart, and thence diffused by the arteries in all directions over the body. There is not a fibre, not a particle of the flesh of the living body, which is not directly or indirectly visited by the life-giving stream of oxygen, and as the carbon, which has become aeroform in the combustion of a solid body, (as carbonic acid gas,) rises from the hearth, so the blood, when, at the termination of the arteries, it has effected the union of the oxygen with the combustible substances, rises in the veins from the feet, the abdomen and the hands, again up to the heart, and flows into its right chamber.

But wood, like every other combustible on the face of the *earth, existed*, and the atmosphere with its oxygen floated

around it, and yet no fire arose wherewith man could warm himself and dissipate the darkness of his dwelling, until, according to an old legend, Prometheus brought down the igniting spark. The poor musician, whose friends, when they visited him in his chamber, were well nigh frozen without a fire, sought to cheer his visiters with the assurance that he had put several dollars worth of wood into his stove, and that there was no want of kindling material. But when one of the guests, at the termination of the short visit, peeped into the stove, he saw a violin lying on one side, and on the other, apart from the violin, stood a lighted lamp.

So, also, the combustible substances in the animal body would have just as little power to combine, through the process of breathing, with oxygen, and so to become a source of animal heat, as the trees of the wood have to catch fire and spread around them light and heat. A Prometheus of a higher kind, the vital power itself, must bring the kindling spark from above, out of a realm of spiritual motion, down into the depths of material existence. This relation of the igniting cause with the warming flame may be made somewhat more intelligible by another picture in the great mirror of external nature.

35. THE GENERATION OF HEAT BY ELECTRICITY.

We have first a few words to say respecting the origin and the nature of *electricity* itself.

The beautiful, shining, sweet scented substance, often transparent, for the most part of a yellow color, and of a resinous nature, called *amber*, which is principally brought from the coasts of the Baltic, is well known to my young readers. It is wrought into various articles, such as beads, as an ornament for ladies, and as mouth-pieces for pipes, and in many other

. It is burned as a perfume, or dissolved in spi
and in various oils, it furnishes a good varnish.
people of ancient times, like us, took pleasure i
amber, and attached to it the value, although i
the hardness nor the weight, of a precious stone.
that this substance was known among the ol
and that it is mentioned perhaps by Isaiah, ch. 54,
antiquity, the Greek, *Thales*, who live
Christ, was struck by the property, which
as observes in amber, sealing wax, glass
the property of attracting light subst
straw, ashes, &c. But a ball of a
upon a slight friction, the power no
but also to repel the same, as m
is made of the pith of the elder, an
are used for the purpose. Alt
such as jet, precious stones, and
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The agreement of electricity with magnetism is especially striking. Magnetised iron attracts other iron. But there is observable at the two ends of a magnetic needle, an opposing influence. One end of the needle, when it can move freely, turns to the north, the other to the south; when two magnetic needles approach one another, those ends, which point the same way, repel one another, while the north pole of one attracts the south pole of the other, and the south pole is drawn towards the north pole. There are here, of course, the two opposite poles connected in one and the same iron rod or needle. In electrised bodies the case is otherwise. When a pith-ball, suspended by a fine silk thread, is brought near a rubbed stick of sealing wax, or an amber ball, it is attracted by these bodies, during their electrical excitement; it does not remain attached to the wax or amber, but after a time it is repelled. It has consequently received the same kind of electricity; and it separates itself from the wax or amber, just as the south pole of one magnet flies off from the south pole of another. Let another electrised stick of jet, of sulphur or amber, be brought into the vicinity of the pith-ball, while the ball, by virtue of the mutual repulsion, is at some distance from the wax or amber, and it will be repelled by jet or sulphur also, but not by an electrised rod of glass, towards which it immediately flies, remaining attached to it, until the ball has taken from the glass also the same polaric excitement, when it quits the glass and rushes to the electrised sealing wax, as often as the mutual play of repulsion and attraction, from the wax to the glass, from this to that, is repeated anew. The experiment may be tried directly with sticks of glass and sealing wax. So soon as they have become electric, one stick of wax or an amber-ball repels another, but is attracted towards a glass stick, which latter is repelled in like manner by other electrised glass sticks, but attracted by sticks of wax. In this case, therefore,

the two opposite polarised states appear not in one and the same body, as in the magnet, but in two bodies of quite different kinds. It is not, however, the composition of the electrised bodies, nor the degree of their solidity, neither the combustible nature of resin, nor the incombustible nature of the precious stone, upon which the polaric condition is grounded, so that to one of the two kinds of polaric action the name of *resinous* electricity can be given, while the other kind of electricity is called the *vitreous*. But the production of the two different states depends on other circumstances. When glass is rubbed with woollen, silk or leather, upon which is spread a combination (an amalgam) of mercury, tin and zinc, that electric condition is produced which is directly opposed to that of sealing wax; on the other hand, let the glass be rubbed with a cat's felt, then this last takes the vitreous electricity, but the glass assumes the resinous. Just so the resinous electricity manifests itself in the sealing wax, when rubbed with woollen, but when sulphur is used instead of woollen, then the sulphur shows the resinous, and the sealing wax, contrary apparently to its nature, the vitreous electricity: an inversion which takes place even in the case of the amber, when it is rubbed with sulphur. The character of the electrical state, consequently depends, not alone on the quality of the body in which it is produced, but also on the nature of the influence which has produced it. Two bodies, sustaining a certain mutual relation, form a polaric opposition, like that of oxygen and a combustible body, an opposition, in which one appears as the mover, the other as the moved, the former as giving, the latter as receiving, or, to speak scientifically, the one as positive, the other as negative.

In regard to the production, as well as the communication of electricity, a very remarkable difference exists in different bodies. The bodies already mentioned become electric by fric-

tion, always however in that part of their surfaces, which is subjected to the exciting influence. Metals, on the other hand, become, not perceptibly, or only under certain circumstances, electric, by friction, yet they are, however, in a high degree capable of communicating electricity, the action of which is not confined to that part of the surface of these conductors which is in contact with the electric body, but is spread over the whole.

This difference of bodies in regard to the susceptibility and conduction of electricity recalls what has been said respecting the capacity of different bodies to conduct heat. Precisely those bodies which are most fitted, by combustion with the oxygen of the atmosphere, to give out heat, are the worst conductors of heat, while incombustible bodies, or bodies which are hard to be ignited, such as stones and metals, are the best conductors of heat. In the same way the metals readily conduct and diffuse electricity, while the substances already mentioned, which are easily rendered electrical by friction, such as glass, amber, jet, silk, are so little capable of conducting electricity, that they are employed to confine the electric fluid or to collect it at a certain point. By means of these insulators it becomes possible to exhibit these remarkable phenomena in all their power and activity. When a metal or any other good conductor of electricity, such as coal, damp earth, most of the salts, living plants or animals, water, and many other fluids, is placed on glass or silk, that is, upon a substance, which opposes an impediment to the rapid communication of electricity, a very high degree of electricity may be imparted to the surface of the body thus insulated. For glass or resinous substances, which readily become electric by friction or other means, transmit electricity to the metal, or any other good conductor, over the whole surface of which it is immediately diffused, while it is either confined to a portion of the surface of

the non-conductor, or passes from a single point to the receiving body. What is here seen is similar to what happens in the case of a burning piece of wood and a metal wire. The wood, from the end at which it is burning, communicates its red heat to the metal wire, which, if not so long, that the heat it receives is dissipated in a measure, in the surrounding air, becomes red hot throughout, while the wood, burning at one end, can easily be held at the other by the hand, without inconvenience from the heat. For wood is as bad a conductor of heat, as glass or jet is for electricity, only that part of the wood, which is on fire, receives the heat, and communicates the same to other objects, or, to use another, and yet more familiar comparison, a drop of ink, which falls on highly varnished wood, or glazed paper, remains standing, until it gradually evaporates, but when a piece of blotting paper is brought into contact with it, the blotting paper immediately imbibes the drop which spreads far around. Good blotting paper, a wick or a sponge, fills rapidly with the fluid, into which only a part of it is dipped, which may be expelled from the wick or sponge by pressure. When a metal wire, made red hot, is placed with one end in cold water, in a few moments it communicates all its heat to the water, and becomes cooled throughout, while a piece of wood, stuck in ice at one end, will burn on at the other.

An insulated metallic ball, which has been made electric, by means of glass that has been rubbed, gives up its electricity, when touched by a good conductor, not only from the point of contact, but also from its whole surface, while the glass, which has become electric, communicates to the fingers, when touched by it, only that portion of the electric fluid present at the point of contact. It thus becomes possible, at once to produce very powerful electrical effects, and this has been the aim in the construction of the so-called electrical machines, and of the receivers of the fluid connected therewith. Here another difference

between good and bad conductors comes to be noted. In the case of the former, as the metals for instance, the electric fluid spreads itself only over the surface, while, in the latter, as in the case of glass, it produces an excitement that extends to a certain degree to the whole mass. When, therefore, the two surfaces of a glass disk are covered with metal or tin foil, leaving a space at their rims, which is covered with varnish or sealing wax, so that the layers of metal are completely insulated from one another, then, by the communication of electricity from one surface to the other, there is produced an electrical condition, polarically opposed; so that the one surface shows itself as negative, and the other positive, or the reverse. The same phenomenon is seen in glass jars, covered without and within with tin foil, excepting the upper part, where a resinous solution takes the place of the tin foil. When, by means of a metallic conductor, the tin foil in the inside is brought into communication with a glass cylinder or disk, rendered electric by friction, the tin foil takes the positive electricity of the glass, while the external coating of tin foil becomes in the same degree negatively electrical. That these two opposite electrical states are produced, is attributed to the capacity of the glass to take an electric polarity on its two opposite surfaces, but that these two conditions co-exist in such close proximity, without canceling each other by their reciprocal action,—this is possible only by means of the glass, which keeps the two electricities apart. While the outer coating, in opposition to the inner, becomes negative, as the north-pole of a magnet creates a south-pole in the iron wire which is brought near it, so the external, negatively electrified coating produces positive electricity in non-electric bodies, and in the measure in which it does this, the strength of its own electricity increases. Through the opposing relation, thus existing between the two surfaces of a coated glass disk or bottle, the one electrical state, whether

negative or positive, serves, the more powerful it is, to increase the other; both mutually produce each other, and to such a degree that, sometimes, the glass lying between them is not capable of resisting their polaric tendency to unite and balance one another: the spark from the one strikes to the other through the insulating partition, and perforates or breaks the glass. But when the polaric action is not increased to this excess, and when several bottles or jars, coated outside and in, as above mentioned, are so united, that all the inner surfaces are in connection one with another, and all the outer surfaces are united in like manner, then we have an electrical battery, as it is called, by the uncommon power of which, human art has imitated the lightning. We will here mention briefly the phenomena, which have been observed in connection with electricity thus powerfully excited.

When the ball-tipped wire, connected with the external coating of an electrical battery, is brought close to the similarly tipped wire, connected with the interior of the jars, then we have thunder and lightning on a small scale. A light of great brilliancy flashes from the two ends of the wires, that are brought near to one another, and an explosion is heard according to the strength of the charge. When an animal is put in connection with the wires of a powerful battery, and the stroke passes through it, it is killed as suddenly as by a stroke of lightning. When one takes in each hand the wire of a less powerful battery, he suffers a peculiar spasm of the joints of the arms; and this sensation may be felt by any number of persons taking hold of hands, the person at one end taking one wire in his hand, while the person at the other end is in contact with the other wire. The electric spark, even when it is weaker, inflames the above mentioned combination of oxygen *and hydrogen*, and converts into water these polarically op-*osed gases*, which, by the suddenness of the transformation,

shiver into pieces even strong glass vessels; and conversely, by an increased degree of electricity, water is decomposed into its gaseous elements. Paper may be perforated by a weak electric spark, and, by a stronger spark, even plates of wood and glass; bodies easily inflammable are set on fire, and metallic wires are made red hot by the electric spark.

And here first we meet with that property of electricity, by which, like the fire of a burning body, it is seen to be a source of heat. An affinity was perceived in ancient times between electricity and heat, in the circumstance that electrical bodies, such as amber, are most easily electrised by friction when they are heated.

As heat promotes the growth of plants and animals, so likewise does electricity. The process of vegetable growth has been accelerated by subjecting the seeds of plants to a gentle current of the electric fluid, and even human beings have experienced a healing influence in various diseases from being subjected to the repeated action of electricity,—the patient being insulated upon glass or jet.

A peculiar forming power is disclosed in electrical currents, when they pass through a pulverised substance, which becomes arranged under their influence in figures, which take a regular ray-like or feathery shape, when the electricity is positive.

The rapidity with which an electric stroke passes through a wire from place to place is so great, that it exceeds the swiftness of light. Light traverses a space of nearly 192,500 miles in a second, the electric stroke passes through more than 280,000 miles in the same time. Although the spaces in which the latter measure has been ascertained, are not, as in the case of light, diameters of the earth's orbit, of many millions of miles, but only distances on the earth's surface, yet the extraordinary perfection of the instruments devised to mea-

sure time and space, makes up for what is wanting in respect of an external basis of observation.

We have in the first place referred only to that analogy to heat which is found in the polaric properties of the common electricity, produced by friction. Before we pursue the topic any further we must first notice in passing a grand phenomenon of nature, which, both in its origin and effect, is of the nature of electricity.

36. THUNDER STORMS.

That artificial storm with lightning and thunder which was caused, to the amazement of all beholders, by a certain *Anthemius*, a skilful mechanician and architect, in the times of the emperor Justinian, in the 6th century, may have resembled, perhaps, those artificial storms produced in our theatres by a peculiar machinery, and the sudden ignition of various combustibles. This kind of imitation has as little real resemblance to a natural storm as a wax figure to the living human shape of which it is a copy. Somewhat otherwise is it on the other hand with those storm-like phenomena which are presented by the electrical apparatus. When the model of a house, according to Lilliputian measure, formed of paper or wood, is set on fire by the electric spark, and when the wires of a charged electric jar are brought in contact with another similar model, provided with a lightning-rod, through which the electric fluid passes without setting the house on fire, then we are dealing, although upon a very small scale, with the same natural power, which, in the upper regions of the atmosphere, generates lightning and thunder.

The same electric condition which we produce by friction, or, as we shall see hereafter, by merely laying metallic plates

one upon another, and again separating them, takes place continually between the atmosphere and the surface of the earth. It goes on increasing to a certain height, so that the electricity of the upper stratum stands for the most part in stronger opposition to the electricity of the earth's surface, than that of the lower strata. In clear weather the electricity of the atmosphere is generally positive, that of the earth negative. In a cloudy sky the electricity of the air is sometimes positive and sometimes negative, about as often one as the other. The air is not, as a whole, electrically opposed to the earth, but even single strata and masses of vapor may be more or less opposed to one another.

All these electrical relations between the earth and the air, and between the different masses of vapor and air in the higher regions of the atmosphere, are usually regulated by imperceptible discharges, and a tendency to equilibrium; the ascending vapors, the descending water of the atmosphere, the low floating mists and clouds, give out their electricity to the material substances which are in an opposite electric condition, and, as the explosion of gunpowder ceases so soon as its combustible ingredients have combined with oxygen, so every trace of electrical action vanishes when one of the two opposite movements has, like a ball falling into the hand, come to a stillstand. Yet in this gentle flowing of the electric fluid from above downwards, and from the earth into the atmosphere, perceptible to the eye in those phenomena which are sometimes seen at night on the pinnacles of steeples, on the masts of ships, and other perpendicular objects, and even under certain circumstances, on the tips of the fingers held up in the air,—a phenomenon which the people of ancient times attributed to the propitious vicinity of the Dioscuri, Castor and Pollux, but which our ancestors named St. Elmus fire.

Vegetation, also, has a very considerable influence on the development of electricity, and it is reckoned that the electricity which is called forth by a field of 25 square fathom would suffice to load a battery, heavy enough to kill an ox or a horse. The evaporation of the waters of the sea also has a great influence in increasing atmospheric electricity; for not pure, distilled water, but water with an admixture of foreign, and especially salty particles, is very favorable, while evaporating to electrical activity. The electricity of the air, however, is equalised by every shower, by every breath, by the shadow of every cloud, producing coolness as it passes. The electrical condition of the air around us may be changed more than twenty times in a day, and may be indicated as a positive and then as a negative excess by our instruments, when it is imperceptible to our senses.

In general it is remarked, that, when the north or east winds prevail, the electricity of the air is more positive, during the prevalence of south and west winds, more negative. It is found, however, in the same latitudes to be much stronger in still weather than in windy, by day than by night, when the deposition of watery vapor causes the equalization of the opposite states. Manifold as are the ways by which this equalization is effected, they do not always suffice to prevent that accumulation of electricity in the clouds, which occasions the phenomena of thunder-storms.

When, in the warm days of summer, the vegetable world stands clothed in its full green, the rising vapor becomes more abundant, and fills the upper regions of the air with its positive electricity, when, at the same time, the clouds float at such a height that the electrical equilibrium between them and the earth's surface is with difficulty maintained, then those conditions gradually take place, under which storms are most easily

generated. The dry strata of the air act as insulators, like the glass between the tin foil coatings of a Leyden jar, and so the electric charge is increased.

In the winter months, from November to February, thunder-storms are rare. The low hanging clouds, the moist air, the diminished heat of the earth, the greatly lessened evaporation of water, permit no considerable degree of electrical action to be produced. In October and March only a few thunder-storms occur. In April they are, one year reckoned with another, five times more frequent than in March; in May they are twice as frequent as in April; in June more than three times; in July almost four times; in August more than thrice, and then their frequency diminishes, and they are about as numerous in September as in April. In cold countries, for the same reasons, thunder-storms are rarer than in hot countries, yet even under the 75th degree of north latitude, in the climate of New Siberia and Spitzbergen, violent thunder-storms have been known.

Thunder-clouds are generally distinguished by their dark color, and round, distinctly defined outline, circumstances which go to show their high degree of condensation. The height at which they stand, reaches, in hot countries and in the neighborhood of mountains, sometimes to 9000 feet, in the plains of central Europe, to from 3 to 7000 feet; in the cold climate of Tobolsk, the height of the clouds is often only 6 or 700 feet. Before a thunder-storm breaks forth, the air is, for the most part, very sultry, its electrical condition suffers sudden and great changes. The discharge begins, so soon as the moisture of the air has formed a communication from one side of this great battery to another; the electric stroke, whose spark here takes the form of lightning, and whose sound becomes thunder, darts most often, only from one cloud, from one over-charged stratum of air, to another. As, however, the electric condition of the higher regions of the atmosphere calls forth in the lower

regions and in all objects on the earth's surface, the opposite electrical state in the same strength, the electric discharge takes often a direction downwards and towards the earth. The lightning strikes especially such bodies, as are good conductors of electricity, as metals for instance, next to the metals, however, are living organised bodies, plants, and animals. For this reason, it is dangerous to seek protection in a thunder-storm under high trees. In regard to the exposure of the vegetable world in a thunder-storm—it is said that the lightning never strikes the birch-tree, and the same was anciently maintained of the laurel; hence a crown of laurel was placed on the head as a protection against lightning in a thunder-storm. Also the house-leek, (sempervivum tectorum) which is planted on the roofs of houses, is held by the country people to be a good defence against lightning.

It depends chiefly upon the force of the electricity of the ground, whether and with what violence the discharge of the cloud will take its direction towards the earth; whether the lightning will strike. The warmth of the earth's surface and the capacity of the intervening strata of the atmosphere to conduct the lightning, are of great influence. On which account, in some regions of the torrid zones, thunder-storms are so dangerous that, according to the account of *Azara*, in a single storm in the year 1793, in the space of scarcely an hour, the lightning struck 37 times, and 19 persons were killed in the city of Buenos Ayres in South America.

When the lightning strikes the earth, there is not unfrequently a *returning* stroke observed, not only during great volcanic eruptions, but, on a small scale, in the action of our electrical apparatus. In this case, the lightning passes from the earth to the air, or spreads itself far and wide from a point on the earth. Such earth-strokes sometimes hurl stones and earth into the air, and in some cases, have produced effects as

destructive as those strokes that proceed from the air to the earth. The latter, when they fall upon a sandy soil, cause here and there a melting of the quarz-sand, producing the so-called fulgurites.

The lightning does not always ignite the combustibles which it strikes. In such cases, it appears to act like the electric spark of our powerful artificial batteries, which heats metallic wire red hot, and even melts it, but passes through gunpowder without exploding it (perhaps, because the power of the carbon to conduct it does not give it sufficient time.) By using a wet string as a more imperfect conductor, by which the electric spark is communicated to the powder, the powder immediately explodes. A ship, called the New York, was struck by lightning twice in one thunder gust. It spread through the whole vessel without setting it on fire, and without injuring any one. Indeed one of the passengers, who had suffered for a long time from lameness, all at once regained the use of his limbs, in consequence either of the fright or of the electric influence. All the knives and forks on board became magnetic through the effect of the lightning. It was observed of the magnetic needles, which were all in one room, that some of them became more powerfully magnetic, while others had become weaker. In other instances, the electric influence confines itself to the metals in the vicinity of the place struck by lightning. Thus a house has been struck, without being set on fire, or without injury to its inmates, while the metallic works of the clocks in the house, and even the wire on the thatched roof, was melted. In another case, the gold upon a gilt watch-hand was melted and transferred to the lead, of which the case was made, and which thus became gilt.

It is true it is the conducting power of the moist air, by means of which the lightning strikes the earth, for through a stratum of the air of one or more fathoms thick it would hard-

ly be able to pass, yet rain contributes at the same time its part to diffuse the discharge of electric clouds, for every drop of a heavy shower brings with it a considerable portion of the electricity of the air to the ground, and there an equilibrium is established between it and the opposite electrical state of the earth. Hence the violence of a thunder-storm is gradually lessened, when the rain accompanying it is long continued.

In our latitudes it happens not seldom that thunder-clouds form below the tops of mountains. Above, the sky is clear, while it thunders and lightens below. The observer, however, who contemplates this imposing phenomenon from above, is not always safe, for the lightning sometimes strikes through the ascending mists. Several years ago, an Englishman was killed in this way. He was seated on the rocky precipice of Rigiculum, watching a thunder-storm over the lake of Zug, (in Switzerland.)

Generally those clouds, that discharge hail, float the lowest of all storm-clouds. Hail is not an infrequent attendant of a thunder-storm. Hail-clouds, which are distinguished by the irregular, jagged look of their outlines, and by their whiter color, when they lie so low, (for there are hail-clouds that float very high,) appear to form the lowest stratum or bed of a mass of clouds in which is generated, on a giant scale, a series of mutually opposed electrical conductors, similar, as we shall see hereafter, to the plates of a voltaic pile. It has often happened that wanderers on mountain heights have found themselves in the midst of hail-clouds, the hail being in the process of formation, and still floating in the air. A close observer (Lecocq,) remarked, on such an occasion, that the hail-stones had a rotatory motion. The cold, occasioned by such masses of ice, in a tolerably high temperature of the surrounding air, can hardly be caused, according to the opinion of some scientific men, by the evaporation of the water alone, so that other co-operating forces

of polaric action must be supposed. Hail-stones, for the most part, appear to be formed of different layers, one over another, having in the centre a snow-like nucleus, or some foreign solid substance, borne by the wind from the soil or the mountain crags. Their size is from several lines to several inches. In the hail-storm at Maestricht, in 1827, hail-stones were picked up 6 inches in diameter. At Clermont, in 1835, ellipsoidal hail-stones of the size of a hen's egg were found, and when a quantity of these stones adhered together in falling, great masses of ice were formed. As the greyish white hail-clouds, below and between the dark black storm-clouds, form only thin strata and strips, so also their desolating effect is often confined to a space of country, not over some thousands, and even some hundred feet in breadth, although it may extend in length one or several miles. There are, however, hail storms that greatly exceed these limits, of this kind was that fearful hail shower that in 1788 fell upon France, extending over two separate strips of land, the length of which amounted to more than a hundred miles, the breadth of one strip being from 2 to 3 miles, that of the other more than a mile. The country between and outside, escaped. Hail rarely falls in the night, still more rarely in winter. Even the countries within the tropics are almost never visited with hail, and the cold regions near the pole very seldom.

Like rain, hail also brings the electric fluid to the ground and helps to equalise it. The electric action, however, is, not seldom, neutralized in a still more imperceptible manner by a gentle transmission of the opposite kinds or states of electricity from one cloud to another, or from the air to those points on the earth's surface, which readily attract and transmit the fluid. From such a quiet and less violent passing of electricity from cloud to cloud, the so-called *Heat-lightning* may arise, although, in most cases, this is nothing but the reflection of a flash of

lightning striking at a great distance below our horizon. The possibility of effecting a gradual, or even a harmless discharge of atmospheric electricity, has been rendered easy to human science, since a closer knowledge has been obtained of electrical phenomena.

37. LIGHTNING-RODS.

When the coating on both sides of a heavily charged Leyden jar or battery is touched with glass rods, no discharge takes place. The charged conductor of an electrical machine may be touched by the hands when they are protected by thick silk gloves, without producing a spark, or giving any shock to the arms, while both the spark is seen and a shock felt, when the conductor is touched with a metal wire having a ball of metal at the end. Since it has been known that certain substances possess this quality of warding off and confining the influence of the electric fluid, there have not been wanting those who have sought to avail themselves of such substances as a protection against the danger of a thunder-storm. A rich nobleman, in old times, who was excessively afraid of lightning, caused all the walls, floors and ceilings of his country seat to be covered with silk; all vessels of silver, or any other metal, were banished from the building. He ate out of glass dishes and plates; his knives, forks and spoons, were made of ivory, which was at least not reckoned among the best conductors of the electrical fluid. He himself went dressed in silk, sate upon insulated chairs, slept in silk in a hammock of the same stuff, suspended by silken cords. Nevertheless, so it is related, the timid man came to a violent end, not indeed by lightning, but by a means somewhat similar. Upon a hunting party in autumn, when no storm was to be feared, he was killed by the accidental discharge of his own fowling piece.

Every means of defence, which man can devise for himself and his dwelling, against the lightning, it is to be approved, if used with due wisdom. There is need neither of silk nor glass, which are very limited in the protection they afford, but we must deal boldly with the fearful power of nature itself, by means that deprive it of its power, and give it a direction, by which, without periling the lives or possessions of men; it can pursue its way from the air to the earth or the waters.

A learned Frenchman, the Abbe *Nollet*, had, before the middle of the last century, observed that a heavily charged Leyden jar, or electric battery, was discharged gradually and imperceptibly when an iron point was brought near to the ball of the wire connected with the inner coating; the electric fluid was thus drawn off and diffused without a shock. A leaden tube, 18 feet long, which was so suspended by silken cords that one half extended out of a window into the open air, became powerfully electric, during a thunder-storm. The flashes of fire, observed on certain iron crosses and metallic knobs on steeples and towers, before and during thunder-storms, were found to be, in accordance with the doctrine of the ancients, a favorable sign for the people dwelling in the neighborhood, for wherever and whenever these signs showed themselves, no danger was to be apprehended from the lightning. These elements of knowledge were thus at hand, and it needed only that they should be made use of, in order that the purposes and wants of man should be met.

At the time Nollet, in France, made his observations upon electricity, there lived in America a man, whose memory not only stands in high regard among us of the present day, but will also find honorable recognition in a far distant future, *Benjamin Franklin*. The distinguished career of this remarkable man had its humble beginning in the peninsular, American city of Boston, where his father was a poor soapboiler. Until his

twelfth year, Benjamin was compelled to work with his father at his trade. At that early age, his strong thirst for knowledge drove him away from tallow and lye-vats, to a calling which better corresponded with the bent of his genius. An older brother, a printer by trade, just at that time returning from England, Benjamin became his apprentice. But reading books was more attractive to him than printing them. Every leisure hour of the day, and often a part of the night, was employed with a diligence, like Duval's, in the study of useful books. Benjamin had just reached his 14th year, when his brother, the printer, proposed to publish a kind of newspaper, or periodical of entertainment. But the main thing, an appropriate selection of articles, at once entertaining and instructive, was wanting in the outset. Benjamin determined to supply the want, and his youthful labors met with such general approbation, that the governor of the province, *William Keith*, encouraged him to set up a printing establishment of his own, and gave him a sum sufficient to enable him to go to England, and purchase there all that was needed for the purpose. This took place in 1724, but not until 1726, did Franklin, then 20 years old, succeed in carrying out his plan. The richly gifted young man did not, however, content himself with printing foreign books; he wrote works for his own press, when nothing of the kind had proceeded from America. In these writings, and in his Pennsylvania Gazette, and in the Almanac which he published annually, there was evinced an insight, and a love of his country, which everywhere found entrance to the understandings and hearts of men. In such books as his sayings of poor Richard, a vein was struck which was of service to all classes, high and low. He knew how to stimulate the desire of knowledge, and to furnish means, whereby the wants and difficulties of life may be relieved, and the welfare, external and internal, of the people, promoted. Even the invention of fuel-saving

stoves occupied him. He took especial pleasure in searching the depths of science. A thorough knowledge of electricity appeared to him to afford the key to many natural phenomena, then unexplained. His inquiries spread a new light over the nature and operations of this power of nature. He was, for instance, the first to present a clear view of the ground of electrical polarity, for from him we have a theory of positive and negative electrical action. He too, this rare man, who was destined by Providence to serve as a conductor for his country in the dark storm, which then lowered over the English colonies, and who, by his wisdom and moderation, did so much to lessen and avert the calamities of the period, became the inventor of those lightning-rods which are now seen on steeples and houses almost everywhere. In the year 1751, he communicated his views of the construction of these safeguards against the destructive force of lightning, in a letter, which, with other letters of a similar character, is addressed to his English friend, *Collinson*. The first experiments, by which the force of the thunderbolt was drawn down from the clouds, and put in the power of man, and it was made plainly to appear that it was of the same nature with the electricity, which is allured from glass by friction, were made, partly with iron rods set up perpendicularly, pointed at the top and insulated at the bottom, partly with paper kites, the playthings of children, furnished at the top with a metal point, and with a cord or string, mostly of hemp, at the lower end of which was fastened a key, or similar piece of metal. To avoid all danger, this lower end was held by a silken string, and drawn towards the observer. When the paper kite was raised in states of the atmosphere indicating a thunder gust, the metal at the lower end of the string manifested the presence of electricity in a very striking way. A rod, pointed at the top, showed the same power of leading off the electricity of the air; and in this case, Franklin observed

that the rod was not always affected in the same way, but was sometimes positive (like glass,) and at other times negative (like amber and jet.) Upon the bursting forth of the thunder-storm, it was remarked that, as often as the atmospheric electricity was discharged by lightning and thunder, (of course within a certain space,) the electrical influence showed itself diminished in the rod, but soon appeared again, and increased.

These first experiments with the electricity of the atmosphere in storms, did not always pass off without danger and hurt to the observer. In Petersburg, on the 6th August, 1753, Professor *Richman* attempted to test the strength of an iron rod as a conductor of electricity, and was killed by the stroke received through the rod from the atmosphere—struck dead, as by lightning. Others remarked that such insulated rods, in certain states of the air, received charges of electricity more powerful than those of our largest batteries.

Franklin, in his high calling, as fosterer of the independence of the American Free States, whose people he had already instructed by his writings in the worthy use of Freedom, delayed not to render his invention of the lightning rod as perfect as possible. When, in 1790, he died, the conviction everywhere existed, not only in all the States of North America, but over the whole continent of Europe, that this great American had not labored in vain, peacefully to allay the excitement subsisting between the earth and the sky in thunder-storms, just as he had helped, in his character of a statesman, to allay the perilous agitation that rose between the expanding freedom of his country, and the power of the great mother state.

The construction of our lightning rods is briefly this: An iron rod, of about half an inch in diameter, and the pointed end of which is either gilded, to keep it from rusting, or made of platinum, is raised to a heighth of from 3 to 4 feet above the roof of the building, which is to be protected, and extended

downwards by the wall of the building into the damp earth or into the water. When the rod is 4 feet above the roof, the circle of its influence extends to a distance of 8 feet; on which account, large buildings, which it is particularly desirable to guard, should be provided with several such rods placed at due distances. In most cases, conductors of this sort will prove effectual, and at least, lessen the violence of the discharges, when a number of these rods stand united within a small space. In this connection it must have been remarked that thunder-storms, passing over cities provided with lightning rods, are much less destructive than formerly, when these safe-guards were not used. There are cases, however, in which all human care and art prove in vain. The electric fluid may be so powerful that the rod is insufficient to conduct it off; it may in this case dart off to some other metallic or organised body in the vicinity of the rod, and, as experience has shown, seriously injure a person who should be seated at a window near the lightning-rod, and chance to be employed with some metallic instrument. The melting of the conducting wire or rod, may interrupt the passage of the electric fluid, and sometimes a violent shower may attract the stroke, not to the rod, but to the building, in which case the danger of conflagration is slight, because the moisture of the roof, by diffusing the electric force, weakens it, and carries it off to the ground with the water that runs down.

In regard to the form and efficacy of the points of the rods, as well as of the rod itself, we may remark the power existing in a small space or quantity, contrasted with mere magnitude. The fine metallic particles in platinum-sponge exerts against the elasticity of the air, a force, many times greater than the pressure of the atmosphere, the influence of which is universal and unlimited, producing a condensation of the gas, which they take into their interstices, which the pressure of several hun-

dred atmospheres can scarcely effect. In a similar way, the fine pulverised particles of the upper layers of the soil, in our fields and gardens, attract the moisture, and especially the carbonic acid and oxygen; and thus communicate a quickening influence to the vegetable germs deposited among them.

A striking example may here teach us, how much, in other respects, the secret, attractive force of minute particles effects, in comparison with the power of large masses, or of mechanical pressure. Human art has attempted, with the instruments designed to produce compression, to apply to several gaseous bodies a pressure, which should exceed several times the pressure of the atmospheric column upon the surface of the earth and sea. By a condensation six times greater than that to which it is exposed in the atmospheric air, ammoniacal gas is converted almost entirely into a liquid, which, however, instantly expands again into a gaseous form, as soon as the pressure is removed. Such an uncommon condensation is easiest obtained when a gaseous acid, combined into a solid body by being united with a metallic or earthy base, is expelled from this union by a stronger acid in an air-tight vessel, and so little room is thus furnished in the vessel, that the expelled gas has to occupy only a small part of its usual space. When sulphuric acid and common carbonate of lime are mixed in a well closed iron vessel, the sulphuric acid combines, as in the open air, with the lime, and the carbonic acid escapes, with a violent effervescence, in the form of gas. When the mixture is large enough, several pounds of carbonic acid can, in this way, be disengaged in a space, which, under the ordinary pressure of the air, would be completely filled with some ounces of the same acid gas. When one portion of the carbonic acid, which is disengaged, presses after another into the confined space, and it becomes so compressed, that it has only about the 36th part of its natural bulk, a remarkable change takes place in

the carbonic acid gas. It now takes the form of a liquid, but, the instant the necessary space is given it, it expands with such immense power and rapidity to its natural bulk, that we are acquainted with only a few instances of so violent an escape of a substance from the confinement, to which human art has consigned it. At first, in the extraordinary rapidity of the change from the liquid to the gaseous form, the heat is withdrawn; and so great a degree of cold is produced, that a portion of the artificial fluid is stiffened into a white, snowy mass. This degree of cold, when ether is mixed with this solid carbonic acid, is, so far as our thermometrical instruments go, immense. A mass of mercury of many pounds weight, when brought into contact with this mixture, is, in a few moments, frozen so hard that it may be hammered. On the other hand, when solidified carbonic acid, under other conditions, is gradually converted into a gas, it may be taken in the hand, without any inconvenience but a sensation of great cold. It is only the liquid, condensed carbonic acid, which, by being suddenly discharged from a glass tube, shivers the tube, and which some time ago caused an accident in the laboratory of the Polytechnic School in Paris, that has been variously described in the public papers. An assistant of the professor of chemistry had prepared some liquid carbonic acid, in the above mentioned way, in a cast iron cylinder 2½ feet in length, and 1 foot in diameter, which had often been used for such experiments. The condensed gas broke the cylinder, and threw the fragments about with such violence, that the assistant was killed, both his legs being broken. Had the explosion occurred a quarter of an hour later, in the crowded lecture room, it would have caused the loss of many lives.

The little tender hairs and bristles, which cover the surfaces of many plants, especially such as grow on the mountains, attract, like the broken, pulverised soil of our cultivated lands

the atmospheric gases, which are subjected in the interior of the plants to a degree of condensation which art can scarcely reach. There is, however, no evidence of violent action, when the substance, so powerfully condensed, returns to its original state as a gas, but the change goes on as gently and imperceptibly as the condensation.

In like manner, the metallic points of the lightning rod take the electrical fluid from the atmosphere and from other bodies in their vicinity, in a way scarcely perceptible, or rather perfectly harmless; they thus destroy the violent character of the discharge, and communicate the electrical influence to the ground in the greatest fulness. The more quiet, hidden method, by which the minutest means apparently are set in motion, is here seen to be also the most effectual; it is the method by which most is obtained, and the end is reached in the safest and easiest way.

38. A SPECIES OF LIGHTNING ROD, USED TO FRUCTIFY FIELDS.

Science, in our times has, by its inventions, made things possible, of the practicability of which, the keenest-sighted of the ancients never dreamed. We have adduced many instances of this sort in the foregoing chapters. We proceed now to another case which, when verified in practice, will redound to the advantage of the husbandman, and the honor of science.

The lightning, when it descends in its majesty and power, is so mighty and destructive, that no living being can withstand it; on the other hand, when it comes in soft, gentle streams, as a continuous flow of electricity, it is changed from a destroyer, into a kindly nourisher and preserver of life. The thundergust, with the terrors of its lightnings and thunders, sets before our eyes a condition of nature, in which the lower, the earth,

is in opposition to the higher, or the heaven, by means of that electric state which can be equalised only by a violent discharge. On the other hand, in the process of still transmission, these two opposites, the earth and the air, the lower and the upper, mutually give and receive, in a steady and peaceful interchange, accompanied by no violence.

Such a quiet interchange is going on continually between the living green vegetable world, and the atmosphere, penetrated as it is with electric forces. Every tree, every weed, is, in its place, through all its leaves and branches, a lightning rod. That an influence is thus exerted upon the growth of plants, rendering the germination of their seeds the more or less rapid, has been known for a hundred years. The two myrtle trees, which *Maimbrai*, at Edinburgh, in October, 1745, electrised for several weeks, put forth buds and fresh branches, while other trees of the same kind yielded to the approaches of winter. The learned Abbe *Bartholon* declared, with great confidence, that electricity has the most powerful effect upon the nourishment and growth of plants. Besides, the curious organism of plants takes nourishment from the atmosphere, in a way unknown to us. The idea, therefore, conceived and carried out by the intelligent Scotchman, Mr. *Foster*, at Findrassie, about a hundred years after the experiment of his countryman, Maimbrai, was natural enough, viz: to apply electricity at once on a large scale for the promotion of the growth and fruitfulness of our useful vegetables, not indeed that electricity which we generate in our machines, and not even the current of a galvanic or magneto-electric apparatus, but the electricity, produced from that inexhaustible source which exists in the relation between the air and the surface of our planet. The experiment, which was made, and by which the influence of atmospheric electricity was directed to this end, was the following:

A piece of land 80 ells long and 55 broad was laid off from a barley field, lying in the north of Scotland, which had been ploughed, planted, and manured uniformly, all over. The piece of land, thus measured, was exposed to the continuous influence of atmospheric electricity, by means of pegs driven down at the four corners, the longest sides of the parallelogram lying exactly north and south. To these pegs, a strong iron wire, going from one to the other, was fastened, and laid three inches below the surface of the soil. In the middle of the shorter sides, (at the north and south) poles 15 feet high were raised. From the tops of these poles a wire passed lengthwise over the piece of land to the foot of the opposite poles, and was there connected with the wire passing under the surface of the ground. The influence of the atmospheric electricity by such a contrivance may be still further increased by burying in the earth, outside the two longer sides, (at the east and west) on the one side a bag of charcoal, on the other a bag containing zinc-plates; and by connecting by a metal wire these two substances, which are peculiarly disposed to strong polaric action. This third wire is placed at the same heighth with the wire fastened at the tops of the poles, and carried through the air by means of poles erected at the points where the two bags are buried. Just in the centre over the field, wires cross, one running north and south to conduct the atmospheric electricity, the other, going from east to west to conduct the galvanic stream. Thus, by means of the wire running round the field, a constant stream of electricity is flowing below, which takes its origin from the mutual influence of the earth and air, going on above, as well as from the two polarically opposed galvanic elements; so that in this way the field is wrought all over, and penetrated above and below, as by a network of electric influence.

The effect of this arrangement upon the seed sown, was everywhere perceptible. The acre, thus experimented upon, bore 13½ qrs. of barley, while the rest of the field bore only the usual quantity of from 5 to 6 qrs. to the acre. The kernels also, upon the piece of land submitted to electrical influence, were so large and sound, that a bushel of the same weighed 2 lbs. more than a bushel of the other.

Upon a small scale also, a similar experiment was made with a like favorable result. Two garden-beds were sown with mustard seed, and to one of these beds electricity was applied; and in the same time the plants grew in this bed 3½ inches high, while in the other they attained to a height of only 1 inch. Although the effect of the above described method of promoting vegetable growth by means of atmospheric electricity, is not so extraordinarily rapid, in comparison with that of an electric stream, artificially generated, by which a French man of science and a lover of horticulture, won his wager, that he would raise cresses from the seed, and produce them fit for the table in the same time that it would take to roast a leg of veal, yet the process we have mentioned is much more powerful and lasting.

The expense of the contrivance we have described was estimated at $5 per acre. Yet this expense decreases in proportion to the space surrounded by the wires, and the apparatus once provided, will last from 10 to 15 years, if the wires are taken up every year, when they have discharged their office, and replaced again at seed time.

These singular experiments of fructifying fields by a means which the art of man obtains from the atmosphere, were certainly worth being repeated, and there is much to be said in favor of the possibility, and even probability, of their success, although there is much also to be said on the other side. In order the *better to understand* the merits of the case, we shall

here make a slight digression, and consider somewhat more particularly the process by which plants are nourished and formed.

39. VEGETABLE LIFE AND AGRICULTURE.

When the eye of man has rested with delight and wonder on the beauty which a rosebush in bloom presents, or an apple-tree puts on in spring or in autumn, when he has gazed, without being satisfied, on the tall lily or the gorgeous tulip, there yet remains a great part of this daily repeated miracle unknown, until a look through a magnifying glass, opens the doors to the treasure chamber of this hidden wonder. A little fragment of a leaf or blossom, placed within the field of view of a microscope, represents in its inner texture a work of high art, the spectacle of which holds our willing attention no less powerfully than that of the delicately formed leaves and many colored flowers. There we see plainly how the forces of life consort with the minute and the tender, how they have their sphere in a manifold variety of parts, which are united into an organised whole that is subservient to the working of a universal soul. In such a specimen of vegetable structure one sees a collection of cells, of tube-shaped and screw-like vessels, of the ingenious arrangement of which, the naked eye knows nothing.

In the internal structure of the less perfect plants, such as the mosses and sponges, only such sap-vessels as resemble little cells, such as the cells in a beehive, and which are arranged along-side and over one another, compose the body of the plant. In the external surface of more perfect plants, and in the leaves and stems of the same, numberless similar cells are observable, frequently expanding into a tube-shape, into bag-like sap-vessels, the sides or walls of which, scarcely dis-

tinguishable to the naked eye, possess, taken together, such solidity and strength, that the under layer of the bark of many trees may be manufactured into rope; and the fibre of flax, hemp, the nettle, and the paper-mulberry tree, may be spun into thread and used in various kinds of weaving. But among all these cell-shaped and cylindrical structures, appear the above mentioned, screw-like, spiral vessels, which seem to be designed more for the sake of communication with the gaseous substances, which plants require for their nourishment, than for the transmission of earthy or salty particles, rendered liquid, and dissolved in water.

By the long, cell-shaped sap-vessels, one is led to imagine a sort of polarisation of these delicate structures, upon which, ultimately, the whole vital activity of material things is based. The several sacks, or little tubes, do not open one into another, they do not, like the veins of an animal body, form one continuous canal, but they are closed at their ends with a fine membranous texture, through which the sap must transpire from one of these little sacks into another.

Within, into the minutest parts, as well as on the largest scale, the life of the plant, its nourishment and formation, all rest on the polaric opposition of a higher and a lower, by which a constant ascending and descending of sap, a kind of circuit is effected. The tree receives its nutriment, receives water, for instance, carbonic acid and nitrogen, not out of the ground alone, but also from the air; the ascending sap, derived from the earth, requires, if it is to receive the peculiar properties, by means of which the different kinds of plants are distinguished, the polaric influence, which comes from above and is generated and maintained by the sunlight, and those substances received from the air. If the trunk of a tree is cut round and deprived of a portion of its bark, it becomes apparent that there is an effort to form new bark, by the issuing of the sap from the upper as

well as the lower edge of the cut, the tree, however, dies if the cut is so broad as to obstruct the polaric interchange between the sap from above and the sap from below, and thus to break the circuit.

That the green leaves of plants attract the chief means of vegetable life, carbon and water, from the atmosphere, is proved by many observations. It may be seen, on a small scale, how vine leaves, when enclosed in a glass globe, withdraw from the air that passes through the globe, all the carbonic acid which the air contains, even though the air passes through with the greatest rapidity. And not only carbon, but nitrogen also, in so far as it exists as a component part of the sap, fruits, or bark, of plants, is drawn by them from the air, and incorporated into their own substance.

J. Liebig, in his chemical letters, points us to those facts by which this consumption of air by vegetables is ascertained. Our better sort of meadow land, without manure, containing carbon or nitrogen, yields yearly a rich produce in hay, among the component parts of which, chemistry discovers 46 per cent. of carbon and 1½ per cent. of nitrogen. The amount of nitrogen in the produce of a meadow of this sort, which receives no manure, containing nitrogen, is much larger than that of a wheat field, which has been manured in the usual way. For centuries, in Hungary, tobacco and wheat are obtained from one and the same field, without the use of manure containing nitrogen. That substance, the plants obtained not from the soil, but from the air. Every year our beech, chesnut, and oak forests put forth leaves; the leaves, sap, chesnuts, oak and beech acorns, the cocoanut, and the fruit of the bread tree abound in nitrogen, not obtained from the ground. From an acre of land, which we plant with mulberry trees, we get, in the form of the silkworms and their produce, the nitrogen of the leaves on which the worms were fed; the silk alone contains over 17

per cent. of nitrogen, and this crop is renewed every year without the necessity of furnishing the soil with nitrogen from manure. In Virginia, on one field so much wheat was raised that the proportion of nitrogen in the grain might be estimated at, at least, 22 lbs. to the acre. If the nitrogen had come from the soil, many thousand pounds of animal manure would hardly have sufficed to produce this 22 lbs. With the consumption of nitrogen through the leaves, proceeds also the consumption of carbon, the latter, the proportion of which, in our ordinary cultivated fields, exceeds more than thirty and even forty times the proportion of nitrogen, can as little proceed from the ground as the nitrogen. When, therefore, in the case of beets and potatoes, we bring into account the carbon and nitrogen, not merely of the roots, but also of the leaves and stems, it appears that in these vegetables, with all the carbon and nitrogen contained in the manure, no greater quantity of these substances is found than in the grasses and weeds, which are produced within the same space, and which have received for their nourishment no manure at all, but only atmospheric substances, and the particles of a mineral nature in the soil.

While from these facts it appears that these plants imbibe in part, at least, from the atmosphere, the nourishment which they require, which certainly may be aided by the electric agencies of the atmosphere, we must nevertheless not overlook the undoubtedly favorable influence, which the supply of nourishment through the roots, has upon the growth of plants. The consumption of the carbon of the atmosphere depends entirely on the superficial size of the leaves. A plant, the superficies of whose leaves is only half as large as that of another and more flourishing plant of the same kind, probably imbibes only half as much atmospheric carbon as the other. The young plant of our fields, if it had to receive its support merely from the air, could take, in proportion to its small green surface, only a

very small quantity of carbon, and its growth would be very slow, if it did not, at the same time, receive carbonic acid from the more or less richly manured soil. But as, with the aid of this richer source of nourishment, its superficies is enlarged, its power also of imbibing that means of nourishment from the air, increases, and this power it preserves after the supply of carbon through the roots decreases, or ceases altogether.

Besides the power of the leaves to imbibe nourishment, there is the power of the soil to do the same, which must not be overlooked. The clod, broken up and crumbled by the plough and other instruments, attracts the gases of the atmosphere with considerable force, especially the heaviest first, and condenses the same; the nitrogen combines, not only in the atmosphere, but also in the little interstices between the particles of earth, with hydrogen, and by this combination it becomes capable, as ammonia, of being taken in an especial degree into the substance of plants, and into the circulation of their sap.

But the carbon, although, in respect of weight, it appears to be, as a component part of vegetable bodies, far more considerable than nitrogen, which is much more rare, nevertheless, receives its virtue to nourish and unfold vegetable life, only through a polaric connection with other substances, which come chiefly, not from the air, but from the soil. The produce of our meadows may be doubled, by being strewed with ashes and gypsum, and by being copiously watered at the same time. In a similar way quick-lime has been used as a manure in England for a century. After October, the fields there may be seen to be white, as with fresh fallen snow, covered with slackened lime, which, during the wet winter months decomposes and mingles with the soil. To one unacquainted with the effects of this mixture, it can hardly seem otherwise than that the caustic lime should act injuriously upon the soil, because it *destroys that* in it, which has always been considered as the

only means of fruitfulness, the mould, composed of organic elements, and containing carbon and nitrogen. In direct opposition to this previous supposition, the produce of land, to which lime has been applied, is everywhere increased. How this happens, *J. Liebig* has clearly explained in his chemical letters. All our vegetables, the different kinds of grain, turnips, peas, and clover, require for their growth, as already mentioned, besides water and the atmospheric elements, certain peculiar substances in the soil. A field, that yields wheat plentifully, and peas only scantily, with the same manuring, will prove well adapted for turnips, but not for clover or tobacco. The same land, that has borne a good crop of wheat, or other grain, for years, will gradually become less productive, although furnished with the same or even a greater quantity of manure. The reason is, that the supply of mineral substances in the soil, so far as it is capable of decomposition, is exhausted. What these mineral components are, which take such a part in the nature of certain plants, may be ascertained by a chemical examination of the ashes left after burning these plants. It is thus discovered that the different kinds of grain are composed in part of silicic acid (silica,) and that besides this acid, in its easily soluble combinations with the alkaline earth, lime for example, various salts form essential parts in the structure of many of our grains. Some kinds of silicious soils are more readily decomposed by the influence of the air, and the rain, and of mineral substances, in their vicinity, than others. In some parts of Hungary there has been sown, since the memory of man, one year wheat, and another tobacco, without any diminution of the crop. The granite of Corsica crumbles to powder, many kinds of sand-stones are decomposed, while other rocks of the same kind, exposed to the same influences, remain solid and unwasted. Wherever the decomposition of the silicious parts of the soil, and their

combination with alkalies, thus fitting them to nourish vegetation, goes on steadily but slowly, it is necessary that the land, before being used for grain, should lie fallow from time to time, or be planted alternately with potatoes and turnips, which do not take from the soil a particle of the silicious matter, but render a supply of the same possible for the next year. But the generation of such a supply may be effected without these means, if human art comes in aid of the decomposition which is going on. Thus the heavy, clayey soils, contain an abundance of silicious and alkaline substances, and yet the beds of potter's clay are very unfavorable to many plants, because those mineral substances are in a state not adapted to vegetation. By burning the clay into bricks this state is changed; the burnt clay is, in contact with the air, exposed to a continuous decomposition, by which salts, formed from the alkalies, and carbonic or sulphuric acids, appear on the surface of the burnt clay, and are highly favorable to vegetable growth. A decomposition of this sort shows itself chiefly in those parts of walls, where lime, as mortar, comes in contact with bricks, and this indicates the advantageous effect which the mixing of lime with a clayey soil has upon the decomposition of the latter. A man, whose merits are equally great in science and in civil affairs, because in all his profound scientific inquiries, he never loses sight of utility, the celebrated chemist, *Fuchs*, of Munich, has discovered that a solution of potter's clay or pipe-clay, when mingled with milk of lime, is immediately converted into a thick fluid, and that after some time the alkalis mingled with the clay are disengaged, and the clay itself possesses the power to form a gelatinous substance in union with acids. The same thing which the silicious particles, frequently found in clay, undergo, happens to them, when, in the mode of manuring, mentioned above, employed in England, the slack*ened lime* remains a longer time in contact with the clay and

silica of the soil. There goes on a decomposition which is aided by the breaking up of the earth by the plough and other instruments; the decomposition of such kinds of stones as contain silica and alkalis is accelerated, and thus, just as by strewing ashes on the land, the necessary supply of mineral substances is afforded for vegetable growth. But the transmission of these substances into the bodies of plants, is rendered possible only by the water contained in the damp soil. From the surface of leaves the evaporation of water goes on without ceasing; the greater the heat is, the stronger and more rapid is the evaporation, while at the same time the root-fibres work like suction pumps, into which there rises from the damp soil as much water as suffices to fill the vacuum caused by the evaporation.* In the water that rises from the ground mineral substances exist in a state of solution. They are not evaporated, but they remain in the plant as component parts of its substance. When with these mineral substances, the substance of organized manure is taken up in a state of solution, and contributed to the plant, the growth of the latter is, of course, still further accelerated.

From the account here given of the process of vegetable growth, it appears probable that the electric fluid must act beneficially upon plants. The variety of their nourishment, coming also, as it does from the earth and the air, must be the basis of a polaric opposition, necessary to vital activity, upon which electricity cannot be without influence.

40. GALVANISM.

Among all material bodies, the metals, as a general rule, are the most efficient as conductors of electricity, heat and mag-

* *The view entertained* by Liebig, but not well established.

netism. In their pure state, they are impenetrable to the light, and if not completely opaque, as gold sometimes, for example, when beaten into very thin leaves, yet at the same time, they are, of all bodies, the most capable of reflecting light, for the mirror-like, smooth surface of polished metals reflects the sun's light in almost its full strength. The relation which they sustain to light, and also to electricity, is considered as authorizing us to regard the metals as mere receivers, not as generators of the electric fluid, and here is based the division of bodies into electrics and conductors. The discoveries in the department of Galvanism have, in this connection, formed the basis of another system or view, and led to large conclusions respecting the importance and influence of the metals among material bodies.

When two polished metal plates, one perhaps of zinc, the other of copper, each fastened to a rod of sealing wax, or provided with some other insulating handle, are brought together, upon being separated, one plate (the zinc) is found to be positively, the copper, negatively, electric. The electricity, generated thus by mere contact,* may be, like that which is produced in glass by friction, communicated to an insulated metal plate, and there increased to a very great strength. Two plates of the same metal, when brought into contact, take no electric condition, but if, of two zinc plates, exactly alike, one is rubbed by a silver plate, or placed for some time in contact with it, then this zinc-plate becomes susceptible of an electric state in relation to the other zinc-plate, to which, after contact with it, it takes a negative relation.

The electric action which is produced in two metals, or other substances, by mere contact, presents, however, a peculiar

* It is now considered that mere contact is not enough, but some chemical action must take place, in order to disturb the electrical equilibrium.

haracter, by which it is essentially distinguished from common electricity produced by friction. When a plate of zinc is aid by itself in diluted sulphuric acid, the decomposition of the vater immediately commences. For the metal in its chemical elation to the acid, attracts the oxygen of the water, in order, n the form of the oxyde produced thereby, to combine with the ulphuric acid. Thus the hydrogen is disengaged, and rises n innumerable bubbles in the fluid, and the surface of the plate s dissolved in the same measure. But this ordinary process takes place very differently, when, with the zinc plate, a copper plate also is put into the acid, and both metals are directly, or by a conducting wire, brought into contact. In this case also the zinc is dissolved in the acid, the water is decomposed, but the bubbles of hydrogen appear no longer, as before, on the zinc, but on the surface of the copper plate, from which, as ordinarily from the zinc, they disengage themselves and rise. The polaric activity of the two metals may be considerably increased, by piling up between rods of glass or wood, as in the pile, invented by, and named after, *Volta*, a great number of round or four-cornered plates in alternation with pieces of cloth moistened in salt water, or a solution of sal ammoniac, or in water, slightly acidulated with sulphuric acid, in such a manner that first comes a copper plate, then a zinc plate, then a damp cloth, and so on, in a threefold order of copper, zinc, and damp cloth. To the uppermost zinc and the lowermost copper, a wire is attached. The upper zinc end manifests positive electricity, the degree of which is in direct proportion to the size and number of the plates, the lower copper exhibits negative electricity; and every plate nearest to the bottom becomes negative to the plates which are nearest to the top, which, on the other hand, are positive. When the wire or pole of one end of the pile is brought into contact with the outer coating, *and the wire or* pole of the other end with the inner

coating of a Leyden jar, a very strong charge of electricity may be communicated to a pretty powerful battery, such a charge as could be generated perhaps by a certain number of revolutions of the largest glass disks of our electrical machines. Thus it is apparent that the electricity, produced by the contact of metals, polarically opposed, is essentially accordant with that which is produced by friction.

A more convenient and more powerful contrivance is that of the so-called trough-apparatus, in which the acid is poured into a small vessel, made of sheet copper, and in this vessel, the zinc plates are so arranged that they are separated from the bottom and sides of the little vessel, and come nowhere in contact with the copper. From the copper and the zinc proceed wires, which exhibit polaric phenomena, just like the wires at the ends of a voltaic pile, composed as above described, and several such vessels or troughs, so connected that the wire of the zinc plates is always in contact with the copper, generate a very high degree of electric force.

That phenomenon, which we mentioned in describing the simple experiment, which consists in putting a plate of zinc and a plate of copper in diluted sulphuric acid, is presented, in a much more striking manner, by the voltaic pile, or any other contrivance of equal power. The zinc is decomposed in the liquid, and the water is resolved into its two elements, but in such a way that the oxygen is attracted by the positive pole, the zinc, and the hydrogen by the negative, the copper. Or, in other words, the negative pole, which, in the action of the pile in relation to the positive pole, represents the oxygen, calls forth in the water its natural opposite, i. e. the hydrogen; but the other pole, which represents, by its chemical character, the hydrogen, occasions, by its polaric action, a disengagement of *oxygen from* the water, in combination with which that action *may be* equalised and neutralised. The quantity of oxygen

disengaged at one pole amounts to exactly as much as the hydrogen that at the other pole would require, in order, in union therewith, again to become water.

That this is so, may be most readily ascertained by causing the poles of a pile, such as has been described, to terminate in platinum wire, because this metal enters into no combination with the oxygen that is disengaged. From the platinum wire, which is connected with the negative (copper) end of the pile, bubbles rise into a vessel filled with water, just as from the other, which proceeds from the positive (zinc) end. The bubbles at the latter, when collected, amount to one measure of pure oxygen, those at the negative (copper) pole to two measures of pure hydrogen, or, according to weight, the former to 88,94, the latter to 11,06 per cent., accordingly, to just so much of both gases as are required to effect their transformation into water by the electric spark.

This power of the Voltaic pile so to decompose not only water, but all bodies that are composed of several substances, of which oxygen is one, or some substance corresponding in its chemical relations to oxygen, the other being hydrogen, or if a different substance, also similar to hydrogen in its chemical relations, as the metals, for instance,—provided bodies so composed are in a state of solution,—the power, I say, of the voltaic pile, so to decompose them that the oxygenous element is disengaged at the positive pole, and the element polarically opposed to the oxygen at the other, has led to those great discoveries referred to in ch. 18. Muriatic acid is separated into chlorine and hydrogen, the alkalis or alkaline earths into oxygen and their metallic bases, which were previously unknown.

A phenomenon, which first attracted the attention of the inquirer into the nature of this form of electricity which we are now considering, is the influence which the contact of two polarically opposed *metals* has upon the nerves of an animal

body. This peculiarity was discovered in the year 1789, by *Galvani*, professor of anatomy in Padua, and thus electricity, produced by the contact of metals, received from him the name of *Galvanism*. When a copper hook, which was inserted into the body of a frog just killed, came in contact with the iron nail upon which the frog was hung, a contraction of the muscles was perceived, a strong spasmodic action, and these spasms were repeated as often as the contact of the metals was repeated, until with the entire death of the limb, its excitability ceased. The convulsions were the strongest when one of the metals was applied to the nerves, the other to the muscles, or to the extremity of the limb opposite the nerves, and the two metals were put in connection by a good electrical conductor, a metal wire, for instance. The effect did not cease when the exciting influence of the metallic contact was kept at some distance from the nerve; and the Voltaic pile, as well as the single plate, produced the phenomenon also on such limbs and parts of the animal, where the nerves were not laid bare, but lying deep below the flesh; and most strikingly, when the surface of the part selected for the experiment was moistened. Through the so-called Galvanic influence of metallic polarity every nerve is excited to the peculiar action, for which it is designed in the living body: the nerve of feeling to sensations corresponding to its ordinary function, the nerve of motion to the activity of the muscles. If one pole of the column is brought into contact with the forehead, and the other with the hand, a flash of light is perceived before the eyes, while the fingers are effected spasmodically; upon the tongue, the positive pole produces an acid taste, the negative an alkaline; also in the ear a tone is perceptible through the galvanic influence, which is higher or lower, according to the difference of the two poles. The body of a slaughtered animal falls into convulsions, resembling those observed in violent fits of epilepsy; and by experiments on the

body of an executed criminal, it was found that all the nerves, even those by which breathing is affected, were set in action through the electric stream of a Voltaic battery some time after death, for a corpse, on which the experiment was made, began even to breathe anew. This appearance of restored life, however, vanishes with the decay of the nerves, in the case of man and other warm blooded animals, in one or a few hours after death; while it lasts longer in animals of cold blood. Even when the excitability seems to be wholly gone, it may be renewed for a time by the application of acids or alkalis.

In the way in which the electricity of the voltaic pile acts upon animal life, it was at first supposed that there was reason to consider Galvanism as essentially different from common electricity. The difference of the two, however, consists in the fact that the electricity of the voltaic pile is continually equalised and renewed,—it is in a constant alternation of dying away and again reviving; while the electricity, which is produced by friction, increases in one body to a certain strength and then is suddenly discharged into another body, which is in the opposite electric state. The former is more like the quiet light of a burning lamp, the other like the ignition of a body which is suddenly consumed.

That that quiet burning is essentially of a nature not less powerful than that of the lightning, which suddenly breaks forth, is evident from the property of generating light and heat, by which the galvano-electric current is distinguished. By means of a simple trough-apparatus, such as has been described, in which only one zinc plate and only one copper vessel filled with acid, are used for the experiment, a fine platinum wire, through which the electric current passes, may be made red hot, and even be melted. In a pile which consisted of 20 double plates of 6 feet long and $2\frac{2}{3}$ feet broad, a wire $1\frac{1}{20}$th of an inch thick, and 18 inches long, of platinum, a metal ex-

tremely hard to be melted in an ordinary fire, became so white hot that the eye could hardly bear it, and the wire was fused. In the glowing heat of such an electric current even Iridium was melted. The heat produced depends, however, not on the strength of the pile alone, but as much on the quality of the conducting wires. A silver wire allows the current to pass through it without becoming heated, but it instantly grows hot when it is composed alternately of platinum and silver. Between the currents of a strong voltaic battery, (there is one in England which consists of 2,000 double plates of 32 square inches in superficies,) charcoal became so intensely bright that it dazzled the eye; and when the gradual discharge took place through two pieces of charcoal several inches apart, both became glowing hot, and an arc of light was formed between them, so hot that all fusible bodies were melted in it, others, such as quarz, lime, and even sapphire, evaporated.

The phenomena of light and heat in the current of the Voltaic pile differ, moreover, from those which accompany the discharge of a high degree of electricity, generated by friction, in the fact that the galvanic sparks are a great deal shorter and narrower. The sparks produced by the huge voltaic pile, which was just referred to, in England, were only $\frac{1}{30}$th of an inch in length, and were exceeded almost a hundred fold by the spark of the great electrical machine of Van Marum: the power of which, in breaking in pieces vessels and other bodies, is estimated at 9,840 lbs.

41. A RIVALRY OF NATURAL PHILOSOPHY WITH ART: GALVANO-PLASTIC OR ELECTROTYPE.

Who of us that has seen and admired the works of our celebrated masters in engraving, in lithography, and their kindred branches, has not wished that he too might do something for

art? Many a one who has busied himself with the study and description of natural objects, and is of course familiar with drawings, has probably attempted, not merely to draw the object of his study upon paper, but also to etch his drawing with his own hand on copper or steel, because it could hardly be done with sufficient exactness by any one who had not studied the subject with the same interest. But such attempts have succeeded only in a few instances, and that has been when the votaries of science were artists also, as was the case in the last century of the admirable *Rösel von Rosenhoff*, in Nuremberg, and of his ingenious successor, *J. Sturm*: or to refer to another instance, distinguished for early talent and industry, the excellent observer and comparative anatomist, Prof. *Michael Erdl*, in Munich. The work of engraving on copper or steel, of cutting in stone, and preparing dies for coins and medals, is one of the most laborious offices of art, and the tools of the engraver or the lapidary must make many thousands of lines and incisions in order to bring a single specimen to perfection.

In our days, when in all departments, the object is to accomplish the greatest ends in the shortest possible time, and with the cheapest means, a variety of ways has been come at, by which Art is at least divested of much of its former labor. Among these is the invention of the Daguerreotype, by which, without pencil or brush, light becomes the artist, and completes with the greatest exactitude, and with extraordinary celerity, a representation of any object which is placed in the right position.

When the Bedouins, under whose guidance travelers traverse Arabia, and other regions of the East, are asked concerning the ruins which are the remnants of former times, from whom they had their origin, the reply is, if they are not afraid to speak to the enlightened European: "The Dscheni (Genii)

built them in old time." The inhabitant of the East holds firmly to the belief that there is a world of spirits surrounding man, with which, when he understands magic, man enters into alliance, and by the aid of which he is able to achieve things wonderful and superhuman. The natural philosophy of our days has, by natural methods, practised this magic. It has drawn the laws and forces of nature into its alliance, and by their help, it has achieved miracles. Among these magical forces is that of steam, which lifts and carries burthens for hundreds of thousands of human hands, and for many thousands of horses; hammers iron, prints books, spins thread, and performs a hundred other offices. Electricity and electro-magnetism, render to him who knows how to use them, services no less wonderful. For instance, by means of a mere galvanic stream, without any thing else but a certain mixture of acids, copper plates, die-stamps, medals, and other similar things, or the work of gilding, may be most successfully imitated. We propose here to offer a remark or two respecting this singular art, which has been brought to a high degree of perfection by *Jacobi*, and still more so by *F. V. Kobel.*

In ch. 17, we mentioned an apparent conversion of one metal into another, iron into copper. What we are now to consider is similar to that process, both in its nature and even in its outward appearance.

If any vessel be divided into two compartments by a porous partition, such as bladder, or a piece of unglazed porcelain, known as *biscuit*, and zinc and sulphuric acid be placed in one, and a sheet of copper and blue vitriol in the other, the hydrogen which is disengaged does not rise as gas in bubbles, but immediately passes through the porous partition, and combines with the oxygen of the oxyde of copper, which is contained in the blue vitriol, and forms water, and the copper, restored to its pure metallic state, is deposited on the copper plate. When

the coating forms not too rapidly, but under the influence of a moderate electric current, the minute particles of copper form a thick and uniform mass, and attach themselves so firmly and regularly to all the elevations and depressions of the plate, that when the surface, to which the copper thus formed adheres, is examined, the finest marks on that surface are found to be exactly copied, and impressed on the copper. It is not necessary that the plate should always be copper, any substance will serve the purpose, if it only stands in polaric opposition to the zinc. Hence coins or medals of gold and silver, as well as copper or steel plates, may be used with equal success, and impressions may be thus taken from them perfectly faithful to the smallest particular. It is not even necessary to use the original coins or medals, impressions of medals, taken in a metallic mixture, composed 8 parts of bismuth, 8 of lead, and 3 of tin; or impressions in plaster of Paris, or wax, or other non-metallic bodies, first furnished with a thin coating of graphite, are as good for the purpose as the originals themselves. The copper solution is best adapted to this galvano-plastic art, because it allows the coating of copper to be so readily removed.

In the same way, in which any given substance is, by means of electrical influence, coated with copper, silver, brass, or steel may be gilt or plated with platinum, by mixing a proportionally very small quantity of these metals combined with chlorine (chloride of gold and chloride of platinum,) in water, in which common salt has been dissolved, or a solution of cyanide of potassium. The body, which is to be gilt or plated with platinum, is dipped several times into the liquid, and thus put in connection with the copper pole of the galvanic apparatus. After being kept a while each time in the liquid, it is taken out, dried, and the quantity perhaps of silver used for the purpose is observed to have received a new coating, precisely of th

appearance of gold; a piece of steel, thus treated, becomes just like platinum, except in weight. In this way, by means of this galvano-plastic art, copper or iron vessels may be coated with tin or zinc. When we consider the great trouble and unhealthy influence to which gilders are subjected, who have to spread a combination of gold and quicksilver (gold amalgam) over the body to be gilt, and then evaporate the quicksilver by heat, so that the gold may remain in full purity, we cannot but wish that this process of the electrotype may come into extensive use.

Other remarkable formations have also been produced in a similar way, by electricity. Thus, when the zinc-pole terminates in a point, and a metal disk, of silver, for instance, is attached to the copper pole, and both poles are put in a fluid mixture of acetate of copper and saltpetre, the metal, separated from the mixture, is very soon deposited, by means of a weak electric current, in regular and beautiful concentric rings upon the metal plate.

When a very weak electric current passes by a fine wire into a solution, which is to be decomposed, it often happens that the substance, which is separated from the solution, takes a perfectly regular (crystalline) form. In this way many substances have been crystallised, which could not be brought to a state of crystallization under any other conditions.

We return once more to the first mentioned use of galvano-plastic, namely, to multiply copper-plate engravings, medals, &c. What is represented on the original plate or medal in *basso relievo*, is first obtained in a sunken form, from which, an impression may be taken corresponding exactly to the original. Even manuscripts may in the same way be taken off upon a copper-plate with great exactness, and impressions of the same, in great quantity, be multiplied, by simply washing over the letters with some substance, which the weak acid of

the fluid does not attack, and printing off by a press, the writing upon a copper-plate, which is put in connection with the positive pole of the electric stream, by means of which the copper round the letters is dissolved, and the letters are left raised. This process is still more successful with printed books, because the blackness of the letters is more easily and directly transferred by the press to the copper-plate.

From what has been said, it may be seen what the electrotype can and cannot do. Art, properly so-called, the creative power of the human spirit, must first, however, prepare the channel in which the electric current is to flow, that it may thus, by the will of man, who has drawn into his alliance a power wonderful indeed, but not rational, follow its clearly defined path. Thus a rivalry may easily take place between those natural forces, which we have taken into our service, and such works of the human hands as are simply of a mechanical kind, like spinning and weaving, or the laying of stones, one upon another; but where material nature enters into the lists with the spirit that is in man, it soon becomes apparent which is master, and which the nimble and devoted servant.

42. THE NERVES OF THE ANIMAL BODY.

In our consideration of the world of matter, we have several times made mention of the nerves of animals, and of man, and it will be necessary to allude to them yet again, in the next following chapter. It seems to be required, therefore, that we should say something respecting the nerves, as well as concerning the structure and action of our electric and magnetic apparatus.

A long time elapsed before the inquirer into nature, and especially the physician, who occupies himself with the study of

the interior structure of the human body, arrived at the knowledge that it is not the flesh that possesses the power of feeling and voluntary motion, but that this power resides in the little whitish fibres (called nerves) which, on account of their delicacy and fineness are so difficult to be distinguished in the mass of the flesh, the skin and the intestines, that they are often wholly overlooked. The probability, therefore, was that the muscles (the flesh) felt any wounds that were inflicted, and so the opinion prevailed that the seat of feeling was the flesh, while the hair, and nails, and exterior skin, had no feeling.

But further study taught that, when the soft, tender branches of the nerves of a limb are divided, or tied up, the muscle becomes as destitute of feeling as the nails or exterior skin. A limb, the nerves of which are injured, or deprived of their functions by violent means, may be cut and pierced or burned or crushed, without feeling it, and it is then no longer able to obey the will. The palsied man can no longer use his hands or his feet in their accustomed offices, he can neither clutch nor walk, however willingly he would do so. If the injury has affected the optic nerve within the eye, his sight is lost, and midday is as midnight.

And yet such a lamed limb often preserves outwardly a sound appearance. In the eye, when affected by amaurosis, nothing unusual is observable. In the palsied limb the blood in most cases still circulates and flows from the wound, to the pain of which it is insensible: not the mass of the limb, but only a very small part of it is affected, the thread of the nerve, and yet its chief function is lost.

And here we are reminded of the great power which, as we have already said, belongs to the small, to the minute. And not only the nerve, but the whole body of an animal or a man, in its internal structure, points us to the great power of many , united to a common end. When we examine a drop

of blood through a microscope, we discern a countless multitude of little, bean-shaped corpuscula which swim in the water of the blood. They are so small, that 5 or 6 when placed lengthwise, and 20 or 30, when placed side by side, equal the thickness of a human hair. The diameter of these little particles varies from $\frac{1}{4000}$ to $\frac{1}{8000}$ of an inch, the thickness of a hair equals the $\frac{1}{600}$ part of an inch. Every one of these little blood-globules consists of an almost crystal clear body, surrounded by a red coloring substance, like an atmosphere, and composed, in part, of iron, united with a combustible element. The red envelope alone gives to the blood its red color, for in the fluid in which these minute particles float, similar particles are discernible, which want the red colored atmosphere. Thus we discern in the blood of the living animal a collection of minute individuals, millions of which, in their constant, living motion, serve the work of forming and nourishing the whole body.

The muscles, or animal flesh, is of a composition the character of which is more apparent than that of the blood. With a common knife, flesh may be cut into filaments or fibres, which are connected together by a delicate membrane. But we are far from having completed the dissection of a muscle, in this way. Pursuing the examination further by the aid of the microscope, we come to the original, ultimate rudiments of the composition of flesh, filaments, the thickness of which scarcely equals the 40th part of the thickness of a human hair. And it is these, minute delicate fibres, of which many millions must conspire, to effect the movement of a finger, that achieve all those wonderful and powerful motions, by which the invisible life or soul manifests itself. Like the exciting stroke of the electric fluid, the nerve operates in the fleshy muscle, and those fibres, invisible to the naked eye, acting in the zig zag, or serpentine direction of the lightning, contract and work with a

power, which far exceeds the mechanical force of huge masses of matter. How small, in comparison with the whole human body, are the muscles of the jaw, and yet with these we can crack a nut with a force, much exceeding the dead weight of the whole body.

Again, another curious method of composition by means of minute particles is observable in the nerves. The nerves are not, like the muscles, composed of little fibres, but of minute tubes filled with a fluid, oily substance, and running from the brain or spine to that part of the body, where their service is appointed. Six of these tubes, ranged in a row, are only equal to the thickness of a fine hair; their diameter amounting only to the 3000th of an inch. When one of the main branches of the nerves is divided into its separate and smaller branches, it is found that an arrangement exists, different from that found in the case of the veins and blood vessels, where from a branch of larger diameter, a branch of less diameter proceeds. In the case of the nerves, the little tubes, of which their branches are each composed, are separated at the branching point, and a certain number of them, greater or less, unite to form a branch, until, at last, at the final and finest sub-division, only a few of these tubes are found combined, of which every single one finds at a determinate point, the end of its course, unless that opinion is confirmed, which supposes that most of these little tubes of the complete nerves return to their point of departure, thus indicating a double arrangement of the nerves, for the production both of muscular motion and sensation. In this course through the parts of the body, the several tubes of the nerves suffer no perceptible change; each remains the same in form, that it was in connection with the branch in which it originated. On the other hand, in the mass of the brain and the spine, where all the nerves, (12 pair in the brain, 30 in the spine) directly or indirectly, take their beginning and their end, there

are found, here and there, bladder-like enlargements, and other forms of little vessels, partly filled with roundish, half fluid corpuscles. We have already mentioned the elements, of which the brain is composed. Among these elements, phosphorus and sulphur may be of essential importance; but what gives to the web of the nerves, composed of myraids of little tubes, and of which the brain is made up, and to these delicate bladder-like vessels, which are scattered through this web, and into which a part of these tubes are enlarged—what gives them the power to communicate the impressions of the outward world, received through the senses, to the mind in the form of sensation and perception, and to carry to all the members of the body the decisions of the will,—that is not discoverable by the structure of the nerves and muscles, nor can it be conjectured by means of chemical combination. All that we can say at this point is, that a polaric opposition, with its ceaseless alternation, lies at the basis of these manifestations of life. The unmoved nerve and the moved muscle form an opposition of this sort, the nerve occupying the place of the higher, (of a creating and moving power.) In visible magnitude the muscle excels the thread of the nerve very greatly, indeed, the manner, in which the end of the nerve is connected with the muscle, is in many cases wholly withdrawn from our senses. Yet more does the moving of the muscle, which, of course, proceeds out of the nerve, where it is invisible, become an invisible process in the nerve, just as the incitement to bodily perception and sensation withdraws itself from our sensuous cognisance by retiring into the nerve. Finally, all visible motion and form, all the intercourse of the body with the material world, has its beginning and its end in a *somewhat*, not only the working of which, as it goes on in the nerves, but the essence of which is not within the grasp of our understanding. It is beyond the sphere of our knowledge. It is in the soul,

(or spirit,) which preceded the visible body, and will continue to be, when the body is dissolved, because to it, a real, necessary existence belongs, in comparison with which, the existence of the body, without the guiding and determining influence of the soul, is but a shade.

43. ELECTRICAL PHENOMENA IN LIVING ANIMALS.

Not only the metals and other solid bodies, but even very many liquids, when they come in contact with one another, or with solid bodies, show electric action. That even the action of the living nerve is related very nearly to the agency of an electrical polarisation, appears from the phenomena which have been mentioned, and which show that the galvanic fluid, like the living nerve, produces motion and sensation. This is apparent, however, much more strikingly in the case of certain fishes, that possess the power of communicating at will, electric shocks, more or less strong, to men and animals and other bodies. This electricity, proceeding from a living animal body, like common electricity, can be used to charge a Leyden jar, to give forth a spark, presenting all the appearances produced by our artificial electrical machines.

One of the most widely known electrical fishes is the *torpedo* or *cramp-fish*, which is found in the Mediterranean, in the North Sea, the British Channel, in the Atlantic and Indian Ocean, a singular animal, whose body has nearly the shape of a fiddle, and the soft flesh of which is no very agreeable dish. The ancients were acquainted with the power of this animal, by which it so benumbs fishes and other sea animals, that they become incapable of moving for some time,—a power employed partly in self-defence, and partly to secure prey. When this animal is touched by the hand, an electric discharge is felt through the whole arm, producing a tremor and throbbing, and

sometimes also a sudden shock like that of the Leyden jar. This effect, however, is not always felt upon contact; it evidently depends on the will of the animal, whether it will use this weapon or not, and only when it is excited, does it manifest its power. The electric action, of which this fish is capable, is evidently a compensation for a defect under which its body suffers in comparison with other fishes of the same species. Its soft body is not protected by a strong skin, or by those hard projections and spears, with which the surface of most fishes of the same kind is protected. Its movement in the water is rendered difficult by the weakness and shortness of its breast-fins. The cramp-fish is no active swimmer; it commonly lies in the sand or mud at the bottom. But its deficiencies in these respects are supplied by its peculiar physical power; by which it palsies, in the midst of their rapid course, the swiftest of its fellow-inhabitants of the sea, when they do not excel it too much in size. This faculty depends upon a peculiar arrangement in the interior of its body. Just in the forepart of the body, near the neck, there lies on both sides, under the skinny exterior, a quantity of 4 to 6 cornered cells about 1200 in number, filled with a mixture of gelatine and albumen. Strong branches of nerves are spread among these cells, which resemble honey-comb; and it is these nerves, by means of which, the animal sends forth from the brain an electric influence into the solid and fluid parts of the cells.

The most powerful among the electrical fishes, thus far known, is the *electric eel*, (gymnotus electricus,) found abundantly in the streams and standing waters of South America. This powerful animal sometimes reaches the length of a man, and the thickness of a strong man's arm. As much as it resembles the common eel in other respects, it differs apparently to its own great disadvantage, in being very obviously marked with one defect: the long dorsal fin is wanting in this animal,

and at the same time all those little muscles by which that fin is moved are wanting also. This curious animal is deficient also in a body, the tail being the chief part of its length. Yet these defects are supplied by a faculty which it possesses, and which is more powerful than fins or muscles. Down the back and on both sides are found a countless multitude of little, irregular cells, which are formed by the sinewy skin running horizontally and cutting them perpendicularly; these cells are filled with a thick gelatinous substance. Considerable branches of nerves are spread among these cells. It is this peculiar structure, with which the great swimming bladders of the animal are happily adjusted, that gives it that strong electric power which makes it a terror to man and other animals. The inhabitants of those countries, the swamps and pools of which abound with the electrical eel, dread the mysterious power of this fish so much, that they will scarcely venture, even for a large reward, to attempt to catch it, and when they undertake the enterprise, they go to work with the greatest caution. Their fear is not groundless. Powerful horses fall paralysed, when they pass through water which the electric eel inhabits. This formidable animal places itself with its back under the body of the beast of burden as it swims or wades through the water, and gives out so powerful an electric shock that the beast either sinks motionless in the water and is drowned, or, if it reaches the land, stretches itself benumbed on the ground and recovers its strength only slowly. Men swimming have been destroyed in this way. It often happens, therefore, that in those countries, where the electrical eel is found, and where there are no artificial roads and only here and there a bridge, the traveler is compelled to make a circuit, to avoid guiding his mules and horses through the water. For on such occasions, these animals with their burthens, and oftentimes with their riders, have been thrown down, as the electric eel, even when

undisturbed, assaults all animals that enter its waters. As a venomous snake, however, by repeated biting, exhausts its venom so much, that it becomes almost harmless, the electric eel, likewise, by several discharges of its battery, becomes so weak that one may take him without any fear of his strokes. On this account, therefore, when Europeans wish to amuse themselves with catching these animals, they drive a number of wild horses, which may be obtained at a very cheap rate, into the water, that the eels may exhaust their power upon them. But even when the fish has become so weak that he swims with his body half out of the water, avoiding contact with the horses and seeking the vicinity of the shore, it is not wholly deprived of its electric influence. Europeans, unskilled in the hunt, by seizing the little harpoons which have been hurled at the eels, and which remain sticking in the prey, have experienced a shock, exceeding that of the most powerful Leyden jar.

The effect of the shock of the eel is, as observers report, very different in different cases. It depends much upon the size and condition of the fish. When the animal is exhausted in a great degree, then its contact excites only a tremor in the nerves of the arm to the elbow, and a similar vibratory sensation has been frequently remarked as an effect, produced by the cramp-fish. When, on the other hand, the animal is large and fresh, then is the stroke which it communicates to the feet or hands that touch it, so severe through all the limbs and parts of the body, that the individual thus affected, can hardly hold himself up, and for days afterwards he suffers from weakness and pain in his limbs, numbness in the head, and a feeling of general discomfort. When a net is used in catching the electric eel, and only one is caught of full size, and there happens to be caught at the same time a young alligator, perhaps, half the length of a man, the alligator, and any other fishes that

may accidentally be caught with the eel, are, when taken out, found to be dead, and only the eel, the destroyer of the rest, remains, though somewhat weakened, still alive.

All those experiments have been tried with these fishes which go to show the essential agreement of their polaric action with common electricity. The electric spark has been seen, although in size and brightness less in proportion to the violence of the shock than the spark of a large voltaic pile. When the fish is touched with a rod of glass or with the hand wrapt in silk, the glass and silk prove to be as good protectors as in the case of common electricity. On the other hand, the shock of the eel is communicated by metals in all its strength. The eel can give a shock from any part of its slimy exterior, but not from the interior of its mouth. The galvanic fluid, when acting continuously rather than by a sudden shock, is more nearly related to the vital activity of the animal nerves than common electricity. The same is much more strikingly true of the electric strokes of the fishes we have named, of the *tetraodon electricus* of the Indian Ocean, and the *silurus electricus*, which inhabits the Nile and certain streams of middle Africa. The excitement and manifestation of the electricity of these animals is communicated from the brain to the nerves, and depends entirely on the will. The electric eel, the most powerful creature of this sort, whose electric influence extends a considerable distance in the water, when kept in a vessel of water, and in a manner tamed, is able to give a certain direction to the shock or to retain it altogether, making use of his power not every time he is touched, but only when he is excited. It often seems as if the electric fish, before it discharges a shock, first paused to ascertain whether the way was clear, for it sometimes places itself for awhile in contact with the hostile animal, before the latter is made to feel the stroke. The weaker crampfish show still greater care and deliberation. It is the natural

instinct of self-preservation, that moves the animal to proceed with caution in the use of its electric power. When it is stimulated to a frequent discharge of electricity within a brief space, not only its electric force, but the very vitality of the creature, is so exhausted that death ensues. Of two electric fishes it has been observed that by cutting in two the nerves of the electrical organ of one, and thereby destroying the connection with the brain, the animal, thus treated, could give out no more electric shocks, but it lived longer than the other, which was subjected to no such experiment, but only irritated to frequent discharges of electricity.

Another species of electricity, more nearly related perhaps to common electricity, is that which has been observed as peculiar to certain persons. In many individuals the hair, upon being combed or rubbed, gives out electric sparks, the same is the case with the hair of the lion, the lynx and other animals of the cat kind. In other persons, sparks are observed when the skin is rubbed, or upon the taking off of the garments. *Theodoric the Great*, and *Charles Gonzaga*, duke of Mantua, are stated to have exhibited this peculiarity. Possibly the strange and rare cases of a sudden self-combustion that have been known, are to be accounted for in this way.

In regard to those pitiable diseases, happily not always incurable, which flesh is heir to, as epilepsy, convulsions, &c., which resemble the effects of the Voltaic pile, or of common electricity, we are led to conjecture that the electric influence, connected with the nerves, ordinarily imperceptible and always equalising itself, is in these particular cases obstructed in its healthy course, until, suddenly overcoming all obstruction, it pours itself with accumulated force over all the nerves of the body.

44. MAGNETISM AND ELECTRICITY AS FORMS OF ESSENTIALLY ONE AND THE SAME POLARIC ACTION.

The phenomena of which we now propose to speak, have been comprehended under the name of *Electro-magnetism*, by which that unity of the electric and magnetic influences is designed to be indicated, which is directly known by observation.

In speaking of the effects of lightning, we referred to instances that show that electricity becomes a magnetic force in the iron, to which it is communicated. In the ship, which, on account of a defective arrangement of the lightning rod, was struck by lightning, all the iron knives and forks became magnetic, some of the magnetic needles became more powerfully magnetic, others less so, and others again lost their power. The effects thus wrought by atmospheric electricity, are produced also, under other circumstances by artificial electricity and the voltaic pile. A small rod of iron or steel immediately becomes magnetic when an electric current is conducted over it obliquely, and still more when it passes over the iron, at right angles to its length. While, however, magnetic polarisation can be produced by stroking a bar of iron or steel lengthwise, and always in the same direction, with a powerful magnet, a magnetic needle can be deprived of its power by causing the discharge of a strong electric battery to pass through it; whereby it would appear that the direction given to the electric fluid is an essential circumstance. The unity of magnetic and electrical polarisation is apparent also from the fact that the wires of a voltaic pile, even when consisting of a substance, which, under other circumstances, appears wholly incapable of communicating magnetism, attract iron like a magnet, acting indeed upon iron filings somewhat differently from the common magnet, attracting them through their whole length. This mag-

netic property of the wires lasts, however, only so long as the electric current lasts.

The fact above mentioned that a rod of iron or steel is magnetised by an electric current passing obliquely over it, and the fact also that the magnetic power increases with the increase of the electric fluid, have given occasion to another important experiment. Around an unmagnetised piece of iron, of the shape of a rod or a horse shoe, was wound a wire, perhaps of copper, in such a way that the electric fluid from a voltaic pile passing through the wire took an oblique direction over the iron. But by this arrangement the electric fluid as such could not be communicated to the wire apart from the iron, the iron being an equally good conductor; either the wire or the iron, therefore, was covered with a varnish or with silk, woollen and other insulating substances, or the wire was wound round a glass tube, within which the iron to be magnetised was placed. For the action of magnetic polarity differs strikingly from that of electricity in the fact that through all those bodies, which insulate and obstruct the electric fluid, it passes as easily as if they were not present, and only in passing through iron plates does it suffer a sensible diminution of force. While, therefore, this insulating contrivance keeps the influence of the electric current, in its electric form, from the iron, it affords free passage to its magnetic form, and thus furnishes a means of increasing the magnetic power of the iron to a degree never attained by the natural magnet, or a magnet prepared in the common way. Although in the department of magnetism, as elsewhere, the extraordinary power of the small and the minute is evident by the fact that a magnet of only a few grains in weight, will sustain a weight 40 times greater, (a magnet of 7 gr. sustaining 1¼ oz.)* and this power can be increased

* Sir Isaac Newton is said to have worn a magnet in a ring which was capable of lifting 250 times its own weight.

manifold by arming its poles with flat pieces of iron thick at the ends, yet larger magnets, weighing a pound and more, can rarely be increased in power to sustain more than tenfold that amount. The sustaining power of the largest known magnet, the magnet in the Teyler Museum, does not even equal its own weight, for this amounts to 307 lbs., and the weights hung upon it do not exceed 230 lbs. On the other hand a horse-shoe magnet, prepared in the way above described, and weighing 59½ lbs., has been made to bear 2063 lbs. Another, flat-shaped piece of iron, weighing 16 lbs. sustained 2500 lbs.; a hollow iron cylinder, 8 inches long, surrounded by several insulated wires, held 2775 lbs. The strength of the magnetic power, thus communicated to the iron, depends upon the strength of the electric fluid, and on the number of the electric currents which pass obliquely over the iron, or glass tube in which the iron is enclosed. Steel holds it the strongest, but soft iron, cast iron is most susceptible of the electro-magnetic power, and manifests it in the highest possible degree. The power of the electro-magnet, while its polarisation lasts, may be applied to the magnetising of steel by stroking, and a steel rod, when placed red hot at the pole of a powerful electro-magnet, and allowed in this situation to cool, receives a considerable magnetic power.

A further consideration of the influence, which the windings of the wire have upon the iron bar or needle, has led to still further conclusions in regard to the co-operation of electricity and magnetism. The position of the magnetic poles varies according to the manner in which the wire is wound round the iron. If the wire is wound from right to left, that end becomes the south pole which is the north pole when the wire passes round in the reverse direction. But an intelligent man of science of the present day, *Schweiggi*, going yet a step farther, has considered the windings of the electric current around

the magnet in a still more interesting relation. By an ingenious contrivance he has made it apparent that a magnetic needle, through which an electric current passes, when left to move freely, makes a circular motion, round the pole of a magnet brought into its vicinity. By varying the experiment, he has succeeded also in showing a circular motion of the magnet round an electric conducting wire lying in the centre of the circle. In this experiment, small but powerful magnetic bars are employed, being placed in a vessel filled with mercury, in the centre of which the two wires of an electric apparatus unite their currents. As the steel magnet-rods would of themselves float in the mercury, like wood on water, at one of their ends is attached a small piece of platinum, which is 1½ times heavier than the mercury, and therefore answers the end designed: the metallic rods assume the position which a piece of wood, loaded with lead, takes in water; they float perpendicularly. They are then observed to describe a circular path round the point at which the electric currents meet. And not only the magnetic bar, but even the heavy mercury takes a circular, undulating motion, when the poles of a powerful voltaic pile are introduced, at some distance from one another, into a vessel filled with the fluid metal, and a strong magnet is held in the centre between the ends of the poles, or in the neighborhood of one of them, and over the quicksilver. Circular movements in opposite directions, one from the left to the right, the other from the right to the left, immediately commence in the mercury, or more obviously in the water, mixed with a little acid, which is put on the surface of the mercury. At first, in trying this experiment, the north pole of a strong magnet was brought to the surface of the mercury. When the south pole was thus adjusted instead, the motions in the quicksilver at once were reversed; that which before went from right to left, now took the opposite direction, in like manner,

the other movement was reversed also. The same change occurred when the magnet was placed underneath the vessel and brought near to the two points of the electrical discharge.

In these phenomena we see in miniature, and as in a mirror, the copy of a work of the Creator's, the mystery of which stands written in characters of starry light. There, among those shining worlds, there is no stand-still, all, like a man, walking towards his goal,—all are in motion. And in truth it is only one and the same living power that wings the steps of man, and the movements of the stars. This power, as man moves, acts in two modes; first the advancing foot is raised, and then, obedient to the law which direct all things to a centre, it descends again. Thus also, as we shall hereafter see more clearly, operates the power of life in the motion of the moon around the earth, the planets around the sun, and all the suns around we know not what mysterious middle-point. In all, one and the same power is manifested in a two-fold form and direction, in one case towards communion with a centre, but in the other, in harmony with the peculiar relation, which, according to its measure, everything sustains to the all-comprehending origin of all being and motion.

45. THE ELECTRIC TELEGRAPH.

It may seem that we follow a singular arrangement, when, with a description of the electricity of fishes, we connect an account of a method, which science has invented in our days, to communicate the thoughts of one mind to another at a remote distance with a rapidity, which may almost be compared with the rapidity of thought. Something, however, may be said in favor of the arrangement.

When the electric fish, the electric eel, for instance, wishes to kill or paralyse another animal, it is not compelled to attack its

foe with the usual weapons of other fishes; it does not even need to come in contact with the enemy, nor to have him in its immediate neighborhood, but it has only to make use of the invisible magic of its electric power, in order, with the quickness of lightning, to put its will into execution.

What is given to this animal by a singular arrangement of its nerves, man has received in a vastly greater measure in the gift of intelligence, in the power of which, he is lord of himself and the whole material world. Not only by the audible word, but also by the visible sign of this word, he is able to transmit his volitions, his thoughts and the light of his knowledge to other intelligent beings. He guides by his word the trained dog, the swift horse, the powerful elephant. His speech, in the form of letters, speaks to one living in a distant region of the earth, as if he stood bodily at his side, speaks still, when his body has been for centuries reduced to ashes, to a living race of men.

From the earliest times, men have known how to communicate with those living at a distance, especially in times of urgency, by means of the fire-signal. When, however, from hill to hill, over a whole landscape the beacon flames arose, these signals could communicate no very definite information. It could only be learned that some great event had occurred. Vastly more useful, therefore, were the telegraphs, which most of us may have seen, and which by varying the positions of their arms represented letters, syllables, and whole words, and so rendered a regular conversation possible between individuals separated by a hostile army, or other insurmountable obstructions. Still the language, which these telegraphs exchanged with one another from one tower, or steeple, to another, before the eyes of the enemy, or thousands of the curious, depended upon an agreement between those, who had to converse by these means; to them alone was it intelligible. Others, who

lacked the key, could only guess at the meaning of the quickly changing positions of the machine.

These common telegraphs came first into use in Spain and France. The first telegraphic post was made (by M. Chappe,) from Paris to Lille, a distance of 30 miles, and consisted of 12 telegraphs. The erection of this line of telegraphs was soon followed by many others, in and out of France. The advantage, which they afforded for the speedy transmission of intelligence, was unquestionable. The conquest of Quesnay, was by this means made known in an hour's time in Paris. By the present, greatly improved construction of the telegraph, only half that time would be required to convey intelligence over the same distance. At night telegraphic communications are made by illuminating the apparatus, or by a preconcerted disposition of lights. It is apparent, however, how often the state of the weather must interrupt such operations, and how easily a blunder at one of the stations, might occasion mistake.

Of a quite different character are the telegraphs, of which we now propose to speak. By their means the apparently impossible has been made easy. Two persons, living fifty, or indeed hundreds of miles apart, may now communicate their thoughts in words, not, as in the case of the ordinary telegraph, in the space of an hour, or a half hour, but instantly, as if they were seated at the same table. And could a connection by copper wire be established between St. Petersburg and Pekin, and the loss of power, which the electric fluid would sustain in such a space, be avoided, then might a person in the capital of China receive intelligence from Russia in $1\frac{1}{2}'''$, and even *the* man in the moon, if our electric fluid could be carried hither, would hear from the earth in the space of a second, for the transmission of thought by this method is swifter than light. The electric fluid travels in this way about 288,000 miles in a second, a ray of light only 192,000 miles.

But in addition to this all-surpassing speed, such a mode of communication has quite other advantages over the ordinary telegraph. That which is to be communicated to a distan point, is not seen by thousands of eyes, but only at the destined place does it make itself known. The course which the word, thus expressed, takes in the invisible form of an electric discharge, is hidden under the earth, or enclosed in the metal of the wire, passing high over the roofs of cities. But when it reaches its goal it announces itself, not only to the eye by the common telegraphic sign, but also to the ear. He, with whom another communicates in the still, midnight hour, sits perhaps sunk in thought at his desk, or has fallen asleep,—the sound of a little bell arouses him; he listens, the sounds now of a lower, then of a higher, toned bell are repeated, the number of bell strokes, and the difference of the sounds have meaning; first a deep sound, than quickly succeeding, a higher, and then again a low note, represent an A; a low note succeeded by 2 high notes and again a low note signifies B; a low note, followed by no high note, and a high note followed by no low note signify, the first E, the last J; three low notes, following one upon the other, stand for D. Thus, by the number and variety of sounds, every letter of the alphabet is expressed. Between the letters occurs a short pause, between the words the interval is longer. Thus rapidly, as an intelligent child may make out words by spelling, does it become possible by practice to understand the language of bells.

But suppose that the person to whom the distant intelligence comes, is not awakened by the first stroke of the bell, and has lost the first part, or the whole even, of what is thus communicated. Still the loss is not irreparable. He finds, upon approaching the table, at which his magical telegraph is arranged, that everything, which he had failed to hear, is set down there in visible characters. He finds a letter, written not indeed in

ordinary characters, but in points, the peculiar position of which, (corresponding to the different notes of the bell,) and their combination represent alphabetical signs, marked, like the sounds, with regularly occurring intervals between the letters and the words.

It is hardly necessary to remark that this mode of communication is in a much greater degree than the ordinary telegraph, independent of the state of the weather. There is indeed yet more in the power of the individual who thus communicates his thoughts. By different wires, connections may be formed with various points, of which one may be only 2 miles, another 5, a third 8 miles distant towards the east, and still others may lie towards the south, or the west. A communication may be made to one living 5 miles to the eastward, which concerns neither those at 2 or 8 miles distance, nor those at the south or west. It is only necessary to keep up the connection with the desired point, while the connection is suspended with all the other points, and the design is accomplished; just as an individual may personally visit another friend in his chamber, and hold with him there a confidential conversation, of which no one else, far or near, has any knowledge, so may he, who speaks through the electric current, direct his speech to an individual 5 miles off, and at all other points connected with the station not a bell shall sound, or a mark be made on the paper.

It will be asked, how and where such a many-sided contrivance has been arranged? It has been completely achieved by *C. A. v. Steinheil*, in Munich, whose ingenious telegraphic apparatus has commanded the admiration of friends and strangers. The means, by which the telegraph is set at work, and kept going, is very simple, but at the same time extraordinarily powerful. It is based entirely upon the diversion of a magnetic needle or rod from the direction which it takes from the magnetism of the earth, by being subjected to the influence of

the electro-magnetic action of a coil of copper wire. The movement varies according to the direction in which the current passes, in the one case the motion is from left to right, in the other from right to left; and this motion is quicker and stronger, the more powerful the current. When the current, from the point where its discharge terminates, has run through a longer or shorter space, it sets the ends of the little magnetic rod oscillating quickly and powerfully towards one or the other direction, and the ends of the magnet strike on little bells of glass or metal, and thus produce a perceptible sound, and motion is also given to a little vessel, filled with ink, and terminating in a little tube-shaped beak. Through the attraction of the sides of this little tube a small drop of the colored fluid, or ink, presses continually toward the mouth of the tube. A strip of paper, ruled with lines to distinguish the higher and lower tones, is attached to the apparatus, and by means of clock work, in constant motion, rolled off one cylinder and on to another, the paper coming in contact with the motion of the little marking instrument, fastened at the end of the magnetic rod, in such a way that the rod, whose moving end projects beyond the rim of the apparatus, makes a black mark upon the paper, according to the direction and place of the motion, now higher and now lower.

Upon the same principles in general are the telegraphs constructed which connect London with Windsor and Southampton, rendering instantaneous communication between those places possible. In order to send a current from one place to another, one wire only is necessary, if the wire be connected with the ground at its terminations. Along a line of rail road, the iron rails may be used instead of the ground. For the current, which passes along the wire, will return by the ground or iron rails, which are good conductors.

In such phenomena as the motion of the electric fluid and of light, which the mind of man has taken into his service and learned to use at will, we have a type of the difference between the action of the mind and the body. Electricity and Light, although possessing power to penetrate space to an extent almost immeasurable, are indeed both material agents, and yet, distance and time are almost annihilated by them; the connection they establish, although by the material means of a metallic conductor, is miraculously direct and intimate. But what must that uniting attraction of souls be, which requires no corporeal medium, but darts instantaneously through an all-uniting spiritual element from one disembodied spirit to another! Even now the director of an electric telegraph, although confined by the burthen of a body to a certain spot, is able at pleasure to converse with a distant friend, and be present with him in thought and will. What will not be possible when this confinement to the conditions of our planet shall fall away!

46. IMPORTANCE OF HEAT TO MAGNETISM AND ELECTRICITY.

In the course of our consideration of the nature and properties of heat, it has happened to us, as to travelers, who, proceeding to an appointed goal, now through this landscape or city, and now through that, tarry a while at many a point and yield themselves to the examination of curiosities to the right and to the left. In this way we have been occupied, although only as passers-by, with the department of electric and electromagnetic phenomena, and now again we will pause for a few moments over the indistinct inscription of a milestone, which indeed leaves us uncertain of the distance we still have to accomplish to reach our journey's end, but creates no doubt *that* we are still on the right road.

To the action of magnetic polarity, heat does not appear to be favorable. Observation shows that the sustaining power, and consequently the strength of the polarisation of our common magnets, is, in the temperature of a hot summer's day, when the thermometer stands at 104° F., in our attics facing to the west or southwest, remarkably diminished, and still more so when in dry rooms, the heat reaches 122° F. A weight hanging then to an artificial magnet, and firmly held under an ordinary temperature, suddenly falls. Thus it is known also that even the most powerful magnetic rod, by being dipped into boiling water again and again, and then cooled gradually, loses its power. If heated red-hot, it suddenly loses its whole attracting and repelling force, and also its property of being attracted and repelled by the poles of the earth. It is true, a great degree of cold is understood to weaken the magnetic force, yet the diminution by cold is by no means so great as by heat. Light, on the contrary, according to several observations, appears to increase magnetic polarisation, and this especially seems to be the influence of the violet ray of the prism.

That electric action is excited and increased in bodies, adapted thereto, by heat, we have already stated, so that we propose to illustrate the fact in this place only by some peculiar instances, presented by the electro-magnetic activity of many crystallised stones, and especially of the metals.

The observers of nature in ancient times, were acquainted with the fact that tourmaline, when heated, attracts light substances, for the fossil, which an old Roman writer (Pliny) describes under the name of Ionia, appears to have been such a stone distinguished by its various colors, and its beautiful, three-sided pillar-shaped forms. When a crystal of tourmaline, especially if clear in color, with no crack or fissure, and somewhat transparent, is exposed to a moderate heat of 86° F., it becomes, like *a small magnet, polaric*, only with the difference that its

polarity takes an electric form. The one half, taking it lengthwise, shows itself decidedly positive, the other, negatively electric, and this polarisation increases with the increase of the heat, but gradually vanishes, when the heat remains stationary at the same point. And not only heating, but also the cooling of a heated tourmaline crystal, renders it electric. When a stone of this sort, heated to the moderate point above mentioned, is again cooled, its polarisation returns, although previously lost by the heat's remaining stationary, but now, the end, which was previously positive, becomes negative, and the reverse. If, while thus polarised, the crystal is divided into several parts, every single part manifests two-fold electricity, even the smallest splinters are still susceptible of being polarised by heating and cooling. The regular form of this remarkable stone, evidently has a peculiar influence upon its electrical property, for it is only when its little, oftentimes almost needle-shaped columns, are three-sided in form, that they become polaric; with six-sided crystals, the experiment does not succeed.

Tourmaline-crystals of the above description, mostly come from Brazil, Siberia, &c. There is in Germany, in Luneberg, another kind of stone called *Borazite*, which in this respect is more remarkable than tourmaline. Borazite, mostly of a grayish or yellowish white color, and of a diamond-like, though not very great brightness, is found in the shape of little dice embedded in gypsum, with their corners all or in part broken off, and their edges having two surfaces. When one of these little dice is subjected to heat; then, not one pair of electrical polarities as in tourmaline, but four pairs are manifested, the two diagonally opposite corners of the upper and lower back and front sides exhibit one pair, the one being positive and the other negative, and around the upper and around the lower sides, one positive corner alternates with a negative.

Calamine likewise (carbonate of zinc) shows, when crystallised, an electric polarity, and this in an ordinary, moderate state of the atmosphere. Even in crystallised Epsom salts and crystallised sugar, a (weak) electric polarity may be called forth by heat.

Still more than in these cases, is the influence of heat observable in generating electrical action in the metals. When of two pieces of the same metal, copper, or silver, one is heated and the other not, and both are brought in contact, there instantly takes place an electric action between them. When a copper wire is bent in a spiral shape, with one end projecting, by subjecting this end to heat, a perceptible electric action is produced, which takes its direction from the heated-end to the other end, which is bent inwards. When two rods, one of bismuth and the other of antimony are soldered to a larger rod and the point where they are united is heated, the electric fluid, which is generated, passes from the bismuth to the antimony, and in cooling the direction of the fluid is reversed. Thus a number of little rods of these two metals, alternating with each other, may be soldered together and so form a collective column or pile, the electric activity of which may be raised by mere heat to such a degree, that the limbs of a frog, duly prepared, may be made by its means to exhibit spasmodic motions, water and salts may be decomposed, and even the connecting wires be heated. While, to produce a vastly more powerful galvanic action, the co-operation of zinc, tin, or iron with copper, silver, &c., appears to be the most efficient; still thermo-piles, formed of bismuth and antimony, are the most advantageous, for in the series of polaric opposition, generated by mere changes of temperature in different metals, the two just named form the extreme ends, and only tellurium appears to excel antimony as an opposite to bismuth or nickel. Fine, delicate little rods of

from 1 to 2 inches in length, composed of many alternating pieces of bismuth and antimony,—several of these little rods being arranged in the shape of a star radiating from one another,—are so susceptible of the influence of even a slight change of temperature, that they show an electric power under an amount of heat or cold estimated to equal the 6000dth part of a degree of Reaumur. In fact such a slight electrical action becomes perceptible only by means of those artificial, electro-magnetic instruments, constructed as already described. As the weakest electric current, by means of the many windings of the wire, obtains so increased an influence upon the magnetic power that it causes the magnet to deviate from its direction, instruments of this sort are styled electro-multipliers.

An exact observation of the influence of heat upon electrical polarisation and mutual action of bodies, is, on account of the consequences, to which we are led, of great importance. The variation of the degree of the sun's heat on the earth's surface and of the internal heat of the globe occasions, without ceasing, electro-magnetic currents which, like the stirring of a common principle of life, traverse the whole body of material nature. And even in the living bodies of animals and men, made up of fluids and solids, of vessels, nerves, muscles, membranes, and organs of digestion and secretion, the change and ceaseless fluctuations of the outer and inner temperature may produce a constant excitement and diminution of polaric alternation, whereby, as in the case of tourmaline when it is cooled, the different poles may change their opposite positions and the direction of their power, so that what was before positive, becomes negative and the reverse.

47. THE NORTHERN LIGHTS.

With the same propriety with which we connected the consideration of lightning and the phenomena of storms by which it is attended, with the mention of the light and shock-giving action of electrical discharges, we may be permitted at this point, where we have been speaking of the influence of changes of temperature upon electro-magnetism, to give some account of the northern, or rather the polar light. Besides, the phenomena of both, those of our ordinary thunder storms, and those of the polar lights, stand in a relation to one another, similar to that of electricity and magnetism, so that a celebrated natural historian, *A. v. Humboldt*, has named the northern lights, "magnetic storms," in opposition to electric, or common thunder storms.

Both the thunder storm and the polar light stand in many respects, in opposition to one another. The polar lights occur in regions, in which an electric storm is a great rarity. The points of the most common appearance of the polar light fall, not indeed, as was formerly said, upon the two poles of the earth, but not far from the polar circles, namely, upon the northern hemisphere between 60 and 70 degrees of latitude. Although it is probable, according to Capt. *Franklin's* opinion, that northern lights occur in summer, but are not visible on account of the length of the day and the brightness of the twilight, yet one cannot help thinking that this opposition exists between the northern lights and thunder storms, namely, that the former prevail in the coldest months of winter, and the latter in the hottest months of summer. For although Capt. *Ross*, in 66° 30′ N. L., observed the northern lights in September and October, nevertheless, only in mid-winter were they so frequent that *Henderson*, in Iceland, saw the heavens

illuminated by them every clear night; and their brilliancy is then so great that Löwenoern saw, on the 29th of January, the northern light in clear sunlight. Our electrical storms are generally attended by a great sultriness of the air; the magnetic storm of the polar light, on the contrary, at least when it is most brilliant, is accompanied by that fearful winter's cold which makes even the ice crack. To these co-incident effects of the cold, most of our more recent observers attribute the hissing and cracking noise which was previously ascribed to the magnetic storm itself and supposed to belong to it, like the light to the lightning, and the sound to the thunder.

Not only in the vicinity of the north pole, but also in the polar regions of the southern hemisphere, magnetic storms or polar lights occur, and the reason why southern lights are observed much less often than northern may be, not merely because they are more rare, but also because opportunity and place are wanting for careful observers. The practised eye of *Dalton* has often perceived even in England, the distant reflected gleam of a southern light, as others again (January 14, 1831) have seen the light of a northern aurora even so far south as the 45th degree of south latitude. The visibility of the polar lights at such immense distances, is not to be explained by the supposition that this meteor extends to a height of several hundred miles, as it is known that it is scarcely ever more than three times as high as our highest mountains, and can generally be estimated at some thousands of feet. Just as violent thunder storms, although in a decreasing degree of strength, may burst at the same time over a large extent of country, so that an observer in Presburg has thunder clouds rolling over his head at the same hour, in which other clouds, of the same far-spread, electric character, are discharging themselves over Vienna and Lintz; in like manner also, according to the opinion of A. v. Humboldt, the stronger and weaker

appearances of the northern light are at the same time exhibited out of the higher regions of the atmosphere, in the neighborhood of the polar zone in their highest brilliancy, while appearing farther from it, as a less striking illumination. In this way even the aerial reflection, perceived under other circumstances, may render a wide diffusion of such a meteor possible.

For what we know particularly of the polar light, we are indebted chiefly to the observation of one of its modes of manifestation, namely, the north light. What we have said thus far refers especially to this.

Both electric and magnetic storms are considered as essentially analogous in the fact, that both depend upon a disturbance of their equilibrium, the former in regard to the distribution of the planetary, atmospheric electricity, the latter, in reference to the magnetism of the earth. The equilibrium of this distribution, the balancing of the superflux and the deficiency, is, in both cases, restored by a discharge, which is connected with an appearance of light, in the one case, of lightning, in the other, of the polar light. There is indeed in the strength and in the direction of these discharges a remarkable difference. The ordinary thunder storm acts upon all our senses; we see, feel, hear, the power of its shocks, even our sense of smell is addressed by the lightning, which sets houses on fire, shatters walls and trees, destroys animals and men. The electric storm is a force of nature, fearful to man, destructive to the inanimate world.

Quite otherwise is it with magnetic storms. These act only upon one sense, the eye, for the old reports of a hissing and roaring sound, accompanying the northern light, are, to say the least, very doubtful. Capt. Franklin, who, with his companions, observed the northern lights more than 200 times, and

in a most favorable position, very often found himself in the midst of one of these magnetic storms, and neither he nor others felt the least shock, or heard any sound or smelt any sulphurous odor, such as accompanies an electric discharge; the eye alone, undistracted by any other sense, yielded itself to the full enjoyment of the incomparable beauty of this grand phenomenon. No decisive influence of the northern lights is perceptible upon the weather. The electric state of the atmosphere, upon which storms, rain, and snow, depend, appears to be not without effect upon the height, and consequently the visibility, of the northern lights.

And yet it may be said that the action of magnetic storms is far more extensive than that of electric storms. The latter generally extend only over a small space, over a city and its neighborhood; or over a wooded mountain valley, the lightning flames and darts, the thunder crashes and the rain comes down like a flood, while, a few miles distant, the heavens are clear and the electric equilibrium is undisturbed, and only rarely does a great electric discharge, like a continuous row of storms, extend at the same time over several degrees of latitude. On the other hand, the action of magnetic storms is spread out over thousands of miles, over whole hemispheres. Not rarely the northern lights have been seen at the same time in England and Pennsylvania, in Rome and in Pekin. And although the eye may not be aware of the phenomena of the northern lights, yet their far spread presence may be discerned in another way, by the disturbances of magnetic needles. Such disturbances are observable at the same time in the most various regions. A storm-current of magnetic excitement, which is perceptible by our senses in no other way, affects all magnetised steel-needles, from Iceland and the north of Sweden down to the magnetic observatories of the southern countries

of Europe,—manifests itself in the east and the west, and is communicated, probably exhausting itself there, to other masses of iron on the earth's surface in its still career.

The consideration of this remarkable difference between electric and magnetic storms leads us to a comparison between light and magnetism, and between electricity and heat. The light of the flame of a fire is visible at a great distance, the heat is felt only in its vicinity. Light passes silently through plates of glass and all translucent bodies, without injuring them, be it ever so bright; but heat, raised to the melting point, destroys the cohesion of the parts of metals and other solid substances, and converts them into liquids or gases. Light, in its all-animating, all-fashioning activity, would, however, be insufficient for the support of living beings, if unaccompanied by the agency of heat; so the influence of electricity stands much more nearly related to the vital power, even of the most perfect organizations, than the influence of magnetism. An analogy, only incidental and superficial, may be sought between magnetism and light in the fact, that both pass, without any considerable impediment, or loss of strength, through transparent glass and amber and dry air, while these bodies have an insulating effect in relation to electricity, and even interrupt the transmission of ordinary heat. An iron table, on the other hand, conducts heat and electricity, but diminishes the attractive power of the magnet. At from magnet to magnet, through the magnetised needles of a whole quarter of the earth, the excitement of a magnetic storm passes, just as a ray of the rising sun passes through the broad spaces of the atmosphere, the water, and all translucent bodies.

The two meteors are alike in this that they disappear in light. With and by the lightning the disturbed equilibrium of the electric fluid is restored, and with the appearance of the

northern light, the distribution of the earth's magnetism is again equalised. The form of this appearance is indeed very irregular. Not when, as in a storm, dark heavy masses of clouds hang low in the atmosphere, but when there appear, high up, those delicate feathery clouds, which are so transparently thin, that their presence is discernible only as they form a court round the moon, may the presence of a high and brilliant aurora be conjectured. A prognostic of this meteor is commonly found in the irregularities exhibited by the magnetic needle the morning before the night in which the northern lights appear. Instead of thunder clouds, there rises first a brownish or violet vapor, through which the northerly stars shine as through a fog, and which extends to 16 or 20 diameters of the moon's disk. The cloud soon assumes a rounded shape, which in the high north becomes of a white color, a broad bright bow, first white, then yellow, arches itself over the darkness beneath, and the whole now appears as a segment of a huge ball, just emerging above the horizon, and stationary there. This dome of light does not preserve the same form and color for a moment, but it is constantly surging and oscillating. Its color, flashing up now here and now there, changes from violet and blueish white to yellow and sapphire, and then to red and green, and all these colors alternate and play without ceasing one into another. This bow of light remains sometimes for hours before the beautiful meteor takes that highest and most perfect form, which it owes to very powerful magnetic discharges. In this last state, rays or columns of fire rise from the circumference of the dome, of unequal length, mostly straight, though sometimes taking an undulating form, and reaching at times to the zenith. Sometimes the fire-columns alternate with dark spaces like smoke. When the northern *lights* are very bright, these columns break forth, not only from the *arch* of light, but also from different points of the horizon,

as if from the earth, and form, as they appear and disappear, a sea of flame, which delights the observer with its perpetual changes of form and color. The brightness, like the color of this majestic phenomenon, seems closely connected with its motions, the quicker these are, the stronger is the brilliancy, the greater the play of colors. At last, when this appearance has continued for a longer or shorter time, the bases of the fiery rods or pillars move towards a common point of the horizon, which corresponds it is supposed to the magnetic pole of the earth while the upper ends, separating from one another, form a starlike, radiating appearance, which is what is called the crown of the northern lights, and which is rarely seen in its perfect shape, as we sometimes see it represented. With the completion of this pinnacle-form, the whole phenomenon puts on an appearance of repose and stability which was before wanting. The crown, which like a pediment formed of golden rods, over-arches the glittering pavilion, sends forth a quiet light, which undergoes no change, except a decomposition into its prismatic colors. The undulations in the bow cease also, for with the formation of the crown, a way of discharge appears to be found for the magnetic fluid. Soon one fiery column after another vanishes, as if broken off by invisible hands, the light grows pale, and there in the heavenly vault, where just before stood a palace of fiery rays of indescribable beauty, are seen only pale grayish, scattered flecks, like fragments of paper reduced to ashes; and when these ash-gray spots disappear, there shortly becomes visible again, like the blackened wall of a burnt house, the same brownish cloud or fog, over which the bow of the northern lights arched itself. When finally, all that belonged to the grand spectacle has vanished, there are still seen in the heavens the delicate, feathery clouds, which appear to fill the place in relation to the magnetic polar light, *that is held* by heavy, dark thunder clouds in our

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ing, was, for some days, prevented from all egress into day light, and who, as he declared, found after some time that when he held up his hand, a faint light proceeded from it. In all material things, in every stone even, still more in the collected mass of a planet, dwells, although imperceptible to our eyes, a power of self-illumination. The temperature of the coldest winter days of a northern climate, which seems to us an almost insupportable cold, is still in relation to mercury so high a temperature, that this metal is melted by it. The cloudy autumn night of a rocky valley appears to us the deepest darkness, while the night-birds there find a light, which, for the illumination of their way, and of the goal to which that way leads, is all sufficient.

49. GENERATION OF HEAT BY THE SUN'S LIGHT.

Of what avail were the influence of all the other sources of heat, which we have thus far considered, for the nourishment of the trees and seeds that grow in our soils, without that splendid witness of the majesty of God, the Sun, that, with its light, pours forth at the same time also a life-giving heat over all the plants and animals of earth. Seamen, who have spent a winter on the coasts of an island, lying in the midst of the ice of the polar zone, could hardly keep themselves from freezing, even at the huge fires which they kindled in their huts; red hot cannon balls sent forth their heat in the ice-cold room in vain; they could give out no comfortable warmth. Nova Zembla and other similarly situated points on the earth's surface are thus inhospitable for men and unfavorable to vegetation, not only through the fearful cold of their winters, but also by the scantiness of heat in summer. While in many other coasts and islands of the polar zone, the brief, but powerful heat of summer gives to animals, to the soil and its productions, a vigor,

which they do not wholly lose in winter; over Nova Zembla and Spitzbergen, even in summers, rests a constant mist, which, rising from the thawing masses of ice, spreads over the hills of these regions. A country, which, in the course of a whole year, receives the influence of the sun, perfectly free from heavy vapors, only for a few days or hours, can never give us the pleasant sensation of comfort. The effect, produced on our bodies by a month of foggy weather, or by weeks of steady rain, follows also upon the almost constant absence of a clear sunny sky.

The inhabitant of Arabia, in the abundance with which some parts of his country are enriched, can scarcely believe that our regions are occupied by fine, vigorous, cheerful creatures. And yet we all know it is so, and thank Heaven for our richly endowed dwelling, to which the light of the sun, in its life-awakening and warming power, is afforded in such measure that all necessary plants and animals may live and grow. But in the midst of all our plenty and gladness of heart, it is only when we visit lands on which the sun looks down with a yet stronger power, that we learn to know the full beauty and magnificence of this earth. There, where the pure blue of the sky is, for the greatest part of the year, dimmed by no cloud, no mist, where even the moon radiates its pale light with such brightness, that seated on his camel the traveller can distinguish the smallest flower on the ground, where, by the side of fragrant orange groves, the majestic palm ripens its fruits, and a host of bright coloured birds glance among the tree-tops, there, if the attraction of one's country lay only in visible beauty, one could easily forget for a while his dear native home. When one sees there, for the first time in his life perhaps, the blossoms of the plantain unfolded in their full beauty, and, arrayed in their wondrous and fragrant flowers, a hundred other kinds of the most beautiful plants, of which he has seen only single stinted

specimens in our hot houses, or painted representations, when a vast variety of fruits are afforded to our taste, which in their spicy flavour or refreshing influence far excel all our native fruits, and which we hardly knew before even by name, when at the same time from the top of the palm or the tamarind tree, the oriental nightingale (the Bulbul,) pours forth its full toned song, and a troop of lively, graceful animals frolick around us there, then our souls are intoxicated with a delight, such as we scarcely ever before experienced. The spirit within us is raised from the sight and enjoyment of the works of nature to the thought of the Creator, and to the delight which belongs to this thought.

The German is indeed seized with a new sense of the beauty of nature when he passes for the first time over the neighboring Alps, into a land where the olive trees and groves of citrons and oranges grow in the open air, where the blooming myrtle covers the declivities of hills, and rocks and walls are hung with huge flowers, and the vine, hardly needing the care of man, swings itself from tree to tree. And all this fulness of vital power, these delicious fruits, and all the strength and vigor of the animated world, are due to the influence of the sun. It will be proper, therefore, before we proceed to estimate this influence upon us and our planet, to say a few words about this huge fountain of the light of our day, the Sun.

50. THE SUN.

What is the poor, pale light of our earth, (ch. 48,) showing no trace of being accompanied by heat, to the light of the sun; what is our planet, to whose immense masses of land and water, man is in the comparison so diminutive, what, in fine, is all the material magnitude that we know to the grandeur of the sun! More than all other bodies, the sun is a type of the

majestic, all-penetrating power of the Creator. Could an eagle fly through the spaces of our system, although it were to accomplish a hundred feet every second, it would hardly reach the sun in a hundred and fifty years, for the space, which separates our planet from this controlling centre of its orbit, extends nearly 100 millions of miles; the orbits of Jupiter, Saturn and Uranus are at distances of about 500, 1000, and 2000 millions of miles from the sun, and yet the all animating power of the sun's light penetrates through all these spaces, and as starlight, even into spaces a thousand fold greater.

But this power corresponds to the magnitude of this ruler in the centre of his worlds. The brick, which, in the building of a house, is handed from one workman to another, stands in the same relation to the size of the whole edifice, of which it is to be a part, as our globe to the gigantic ball of the sun, for almost a million and a half, (1,384,472) globes, each of the size of the earth, must be piled up to make a world to equal in magnitude the sun, whose superficial contents exceed those of our earth 12,598 times, and the diameter of the earth 112¾ times. Our little companion, the moon, stands at a distance from us of almost 237,000 miles. Suppose the sun were a hollow ball and the earth were placed in the centre, there would still be abundantly more than enough room for the orbit of the moon, the distance of the sun's centre to its circumference being 441,000 miles. If all the planets of our system, from Mercury, which lies nearest to the sun, to the remotest planet known, with all their satellites, were collected in one, they would stand in proportion to the mass of the sun, as a ball of a few ounces in weight to a ball weighing a hundred lbs.

If a child, or any one who looks at things as they appear to the eye, be asked, which is above and which below, the sun or the earth, the answer immediately is: the sun is above, for it

goes high over our heads in the sky, and the earth is below. And yet the fact is directly the reverse. As certainly as it is not the sun, that courses daily and annually round the earth, but the motion of the earth round its own axis and in its own orbit which produces the appearance of the daily rising and setting of the sun, and the annual apparent course of the sun through the signs of the Zodiac, so certainly is the appearance, which makes the earth below, or at the centre, and the sun above, an illusion. Just as a man walking on the surface of the earth, or the ship sailing on the sea, are, in relation to the planet that sustains them, above and outside, so our earth, and all the planets are above and outside in relation to the sun, around which they revolve. The centre of the earth it is, to which, in the whole terrestrial world, the force of gravity tends. What the centre of the earth is as a lower, a *below*, to things on the surface of the planet or the masses which lie between the centre and the surface, the sun is to the orbits of the planets and to the planets themselves. Herein is the superiority of the sun, the ruler of the worlds, over the mighty host subordinated to it, that it is the sun which sustains, not which is sustained, it is the sun which is the foundation, but which is not founded,—it does not rest on the dust-particles that fly around it. Let it be understood therefore that that world, which is elevated high over all the rest by its powers and prerogatives, stands, in reference to its mass, below all others.

Of the peculiar nature, and the efficient cause of the shining of the sun and its warming properties, we know about as little as we know of the interior of our earth, to the centre of which our approaches are very insignificant. If we consider the heat of the water of Artesian wells, and the heat which increases as we descend into mining shafts, as evidence of a constant generation of heat in the interior of the earth, an analogy presents itself between the centre of a single planet, and the

centre of the planetary system, the sun, a resemblance, which is to be sure somewhat like the resemblance of the earth's light (ch. 48,) and the sun's.

The only phenomena, that give us any insight into the nature and quality of the sun's mass, are the spots, which, varying in magnitude and in the duration of their appearance, pass over the sun's surface, always in the direction from west to east, and accomplishing their course from one edge of the sun's disk to the other in about 14 days, circling round the sun in 27½ days. We are thus made certain that the mighty mass is not immovable, but that it moves on its own axis from west to east, like our earth and all the other planets. And although the sun requires for such a revolution, (making allowance for the apparent retardation which, seen from our earth, it suffers, because our planet is at the same time advanced on its path from west to east,) 25½ times more than the earth needs for its daily revolution, still the sun's revolution on its axis, when the relative motion of the surface is considered, is not to be called a very slow movement; every point of the earth's equator, in its daily revolution passes over 1040 miles in an hour, but a point in the sun's equator accomplishes in the same time 4560 miles.

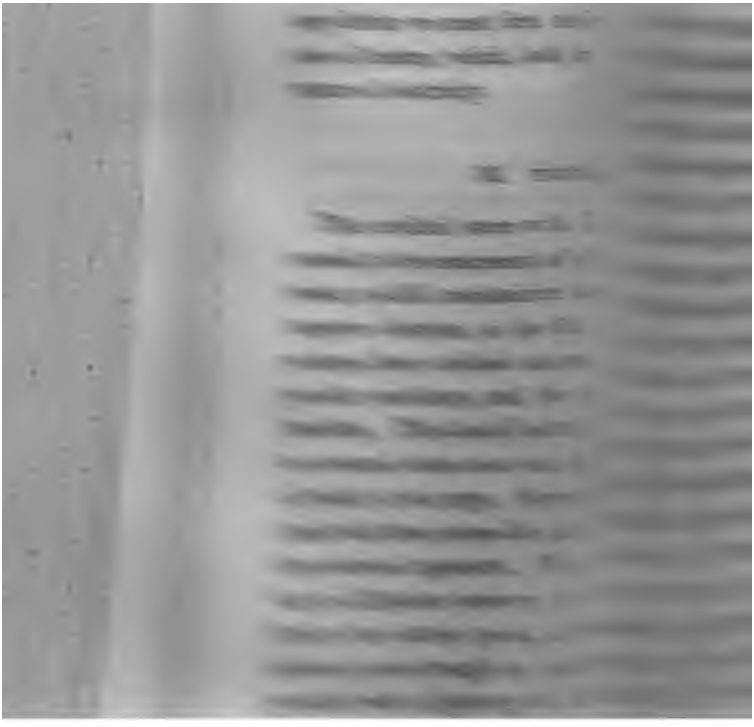
The spots on the sun, formerly regarded as a species of volcanic matter floating on the surface of the fiery fluid mass of the sun, or as smoke ascending from that fire sea, are, as the more exact observation of more recent times has shown, openings or local rents in the luminous atmosphere, which envelopes the body of the sun. How opposite is the relation of the sun to its atmosphere, compared with that of the earth! When, in the case of our globe, the higher region of the atmosphere is dimmed by meteoric masses of clouds, and a rent appears here and there in this dark covering, we descry through the opening the clear blue sky, and the light of the

sun breaks into the darkened space; but when the luminous covering of the sun is rent and opened, a passage is opened indeed for the rays of the nightly stars, down upon the surface of the gigantic body, but the point, lying directly under the opening, suffers a diminution of its day light; the light, that comes to it, not as it comes to the planets, from a vast, luminous, central body, but from a part of itself, is then withdrawn from it in a measure. For the flaming atmosphere of the sun appears to be a fountain of light and heat, not only to all the worlds that circle round it,—but the sun itself, were it divested of this sphere of light, would be a dark mass. When at times, upon the appearance of very large spots, openings have been made, extending over spaces of from 25 to 45,000 miles in diameter, observers have supposed that they saw the dark body of the sun, through powerful telescopes. Mountains, of a height proportionate to the magnitude of the sun, (450 miles high) and floating between the solid mass and the luminous atmosphere, dark, cloudlike meteors, like those of our atmosphere are imagined to have been seen. The height, to which the sphere of light extends above the sun's surface, has, on such occasions been estimated at 2300 miles.

Scanty and uncertain enough is the information obtained from the sun's spots. Other results in relation to the action and motion of our central world have been obtained, not by direct observation of the sun itself, but by the study of other bodies of the starry universe. As the rate, at which a vehicle or steamboat moves may be easiest estimated by the apparently opposite motion of the trees, houses, mountains which we pass, so, in the case of the sun, its motion in an immeasurably greater space may be ascertained, by the apparent motion which has been observed in the so-called fixed stars. For these stars, which were anciently held to be motionless, have "no rest and no haste," but move in curved orbits, around we know not what

invisible centre. It is true, seen from our earth, the progress of those sun-like worlds, on account of their vast distances, seems so small that it is scarcely perceptible in a period of a hundred years, yet it is so considerable, in the course of time, in the case of some of the swifter moving fixed stars, that if the famous Egyptian astronomers, who lived some 1700 or 2000 years ago, could once again survey the starry heavens from the watch tower of Alexandria, they would find the place, of the great star, for instance in Bootes, (Arcturus) wonderfully changed.

If there, in those remote spaces, which the fixed stars occupy, a human eye beheld our beautiful sun, shining like a star among other stars, it would appear to that eye, like a fixed point of light in the heavenly dome; for what is the small amount of the motion of most of the fixed stars, seen even from a neighboring world, according to human standards of time and space. How slight the difference made there by 70 or 80 years. Nevertheless, the stride which our sun takes through space is by no means slow; it amounts hourly to 159,850 miles. Of course the distance, which the sun has to measure, to make up its great year, is incomparably greater than that of our planet in its annual revolution. The earth, although one of the swiftest planets of our system, accomplishes hourly only about 68,500 miles. When, however, the little span of space of 95 millions of miles which lies between the earth and the sun is compared with the distance of that unknown centre, whose influence sets the sun in motion, one has reason enough to suppose the presence of an attractive force which exceeds immeasurably every thing similar to it, which we find in the material world around us. The motion of our sun is toward the apparently inconsiderable constellation of Hercules. Where the centre of its immense orbit is we know not. Our planet, and we upon it are moving along, without perceiving the daily



motion of our solar system; we move here as in the whole course of our mortal being, without seeing whence or whither, as securely as an infant borne in the arms of a loving mother.

In the influence which the sun exerts on our earth and all the worlds of our system, we recognise, on a gigantic scale, the modes and forms in which, in our terrestrial sphere, the polaric opposition between a self-moving agent, and a material movable body is manifested. As the lightning darts from the clouds and discharges itself on metallic points, so everywhere powers of life and motion break forth out of an upper, all-comprehending world of Life, when some material element, disengaged from the confinement and dead repose of material combinations is put into a state, in which it becomes an active agent, a forming power instead of merely being susceptible of formation. Such an inter-penetrating power, proceeding from an upper, super-physical source, was recognised by the wise men of antiquity from the time of *Thales*, the Milesian, in the action of the magnet, although it consists, as we see, only in a moving and a being moved, having its origin in the polaric opposition of the revolving earth to the iron in which, under certain conditions, a like polaric opposition appears. When modern science found means by a spiral wire around a magnet to combine the electric current with the magnetic, and caused the electro-magnetic influence to act upon the magnetic iron rod or bar, then the movement of a second, higher law or order, was manifested: a rotatory motion round a moving centre, a floating up and down of fluid mercury, the rudiment, as it were of a rotation on an axis. In early times, men were acquainted with the fire of Lightning, which, darting forth with instantaneous quickness, strikes a tree or other combustible bodies, and sets them on fire, while it vanishes itself as quickly as it appeared out of the darkness of the stormy night. In later times, obtaining command of the forces of the lightning

by means of electric, galvanic and electro-magnetic instruments, men have been able to accomplish what no philosopher of former ages supposed possible. They have succeeded in arresting the lightning in the midst of its immeasurable speed, and converting it into a steady fire. The glowing current, that flows from the ends of the polar wires of a strong voltaic pile, or of a powerful electro-magnetic apparatus in a moderate stream, is like a flood, whose course never ceases, while the lightning-like, electric discharge, but faintly resembles a shower suddenly falling and as suddenly suspended. While the people of the primeval ages, kindle the fire of their hearths directly from the lightning, and sought with anxious care to nourish and preserve this gift of heaven, now, (in the voltaic apparatus,) the flame of the lightning has become a sort of household fire, which requires neither wood nor oil, and no priests are needed to watch it day and night.

And how altogether differently does this fire of a higher order, although as yet obtained only in an imperfect degree, operate in comparison with the fire of our coal and our wood! Metals, which can hardly be softened by a common fire, are melted in a few moments by the current of our electro-magnetic apparatus; other substances, which we are accustomed to regard as fire-proof, are vitrified or turned into gases; while, in the heat of our furnaces, we are only able to disengage their oxygen from the oxydes of the metals, producing it in its pure gaseous form, or, in combination with carbon, in the form of carbonic acid; by the power of the galvanic fire, oxygen is set free from its incomparably closer union with the metallic bases of the alkalis and the earths. What is the glare of all the torches and fires that man may kindle to the dazzling sun-like brightness of a metal wire, through which the fire-current of a galvanic or electro-magnetic battery passes; or how could the destructive flame, which rises upon the combustion of bodies,

ever rival human art, like the galvanic or electro-magnetic current, as in the case already mentioned of the galvano-plastic art, (Electrotype.)

For the various forms in which the fire of a universal life and motion penetrates the elements of the material world, science has invented various names: Magnetism, Electricity, Galvanism, and Electro-magnetism. For that constant intercourse of the sun with the planetary worlds, from which come light and heat and the tendency to motion round an axis and in an annual orbit, we are yet as far from having any fitting name as we are from possessing a key to a thorough understanding of the actual nature of this intercourse. But this we know, that the moving force, which, as universal gravity, acting from the sun, preserves the planets in their places, and from the planets, keeps their moons in their orbits and gives them, in proportion to the squares of their distances, their different degrees of swiftness, shows itself, by several of its properties, as a polaric agency of a yet higher order than that, with which we are acquainted in electrical and magnetic phenomena. Although the speed of light and yet more of the electric current appears, according to all human standards of motion, to be immense, it is yet measurable, for, from the earlier or later visibility of the eclipses of Jupiter's satellites, at nearer or remoter distances from the earth, the space which light travels in an hour, has been reckoned at over 710 millions of miles, that of the electric current in the same time at 1100 millions of miles. On the other hand, the agency of the attracting force of the sun is subjected to no measurable space of time. The swiftness of the space-penetrating influence of gravity might still be estimated by us by means of the gradual acceleration of the annual course of the planets, although it were ten times greater than that of light, but with all this

onfold increase of numbers, the end is not reached, be-

cause it lies beyond the limits of human calculation. As a thought, at the same instant in which it is conceived, is with its object and apprehends it; as a living arm, at every moment is a limb of the body to which it belongs, because it has never ceased, nor, while life is, will or can ever cease to be a limb of the body, so the moving power of the sun is co-instantaneously at the sun and at the planets; for this power the limits of time and space cease to be. It is all-present like the all-comprehending, all-penetrating agency of the Creator himself.

Nevertheless, the great sun, visible reflex as it is of the majesty of its Maker, must submit to the law of our human intelligence, when we compare the rotatory and revolving motions of the worlds, on which the sun exerts its power, with those which the electro-magnetic current produces in a magnet. When we wind round a magnetic iron bar, an insulated copper wire almost at right angles, we do the same thing in miniature, that the Creative Power has done in so laying the mountain masses and substances of our planet, ring-shaped around the axis that passes through the two poles, that hence arises the globular form of our earth. The globular shape of the earth, may with equal reason be regarded as a cause, as well as an effect of its rotatory motion. The electrico-polaric opposition between the parts and points of the earth's surface, reaching its highest activity, where the section, passing obliquely within a right angle from the circumference of the globe to the axle of the poles, is the greatest, appears to be the cause of the daily revolution of the earth from west to east; while upon the magnetic opposition, connected with the direction of the poles, may depend its steadiness in its orbit, the inclination of its axis, and its annual course round the central body. The sun itself takes part in this formation, and in these motions of the earth, of which our electro-magnetic apparatus, both in its construction and its working, gives us a faint copy; the rotating motion of

the solid mass of the sun, in connection with the character of its atmosphere, may have no inconsiderable influence in the generation of light and heat; but from what source comes that current of power which sets the whole vast structure, with all its parts and spring-wheels in motion, and keeps it moving with imperturbable exactness, that, mortal senses, formed of the dust of earth, cannot descry.

There are, however, besides the power of motion, which acts from the sun without ceasing, other qualities of the great luminary which lie nearer to the daily observation of our senses. Let us proceed then to consider these properties of the sun especially, which arrest the notice, even of the child, and of all nations standing in the condition of childhood.

51. THE INFLUENCE OF THE SUN UPON THE TEMPERATURE OF THE EARTH'S SURFACE.

That at that time of the year, when the days lengthen considerably by the increased duration of the light, the heat also increases, is a fact, familiar every spring to the wildest Indian who inhabits the forest swamps of North America. That the heat of a country, however, depends, not on the longer or shorter duration of the sun's daily light alone, but also on the higher or lower position of the sun, and in some measure perhaps, even on the rotatory motion, which is the greatest under the equator, is taught us by more exact observation. If the only thing to be taken into view were the difference between day and night, daylight and darkness, it might be asserted that the inhabitants of the icy polar regions were equally favorably situated with the people of the torrid zone, where the vanilla grows and palm-groves flourish, nay, that they were even somewhat better off than the latter, for in the course of a year, daylight, directly at the pole, endures not only as long, but on

account of the twilight preceding the rising and succeeding the setting of the sun, even longer than in the hot countries, which lie under the equinoctial line, or the equator. There is only this difference—under the equator the day, at the poles the year, is divided into two equal parts, of which one enjoys the light of the sun and the other is wrapt in darkness. Under the equator the sun stands 12 hours in the heavens every day, at the poles 6 months every year. At the latter point a twilight precedes the vernal and follows the autumnal equinox of several weeks duration, but at the equator, there is a twilight every morning and every evening, but very brief.

But when the sun makes its daily course over the sky at the equator, its rays fall not askant, weakened by the lower and thicker strata of the atmosphere, and, in great part, lost therein, but they strike the earth at midday perpendicularly, and with their full power. And on this fact, the generation of heat by the radiation of the sun chiefly depends, as the twofold signification of the word *climate* depends. Originally this name was given to circles, supposed to be drawn north and south at equal distances from the equator, and the limits of which were determined by the difference of the length of the longest day and of the longest night. Where the length of the longest day is not, as under the equator, just 12 hours, but 12 hours and a half was the boundary of the first climate; where the longest day was 13 hours, was the boundary of the second climate. And so with the increase of about half an hour in the length of the longest day, a new climate was indicated; the number of climates, from the equator to the pole, where the longest day is 24 hours, i. e. where the sun does not set, was 24; so that those countries, for instance, where the longest day is between 16 to 16½ hours, and the shortest night from 8 to 7½ hours, lay in the ninth climate. The duration of that long polar day, on which the sun does not set, from the limit of the polar circle

under 66° 32' to the pole, (under 90°) and consequently through the whole 24th climate, is very different. For in Lapland under 66½° L. there is only one day in the year, (21st June,) when the sun does not set. Some days journey to the north under 67° 18' L. a country is reached, where the sun is above the horizon in summer, and below it in winter, for a whole month; in Wadsoe, (76⅓°) the time in which the sun is always visible extends to more than 2 months, and just as long a time it never rises; at Melville's island (75°) the same time is 3 months and 12 days, at 80° more than 4, at 83°, 5, and at 90°, 6 months. Although, however, the point of time, at which, at the end of the long solar day, the sun should sink below the horizon, must fall upon the day of the autumnal equinox for the region of the pole; and at Nova Zembla (76° L.) the beginning of the 3 months night must be the last of October, and the polar-night, and the reappearance of the sun must begin for the former region, on the 21st of March, and for N. Zembla, on the 11th February, nevertheless, by means of the refraction of the atmosphere, the sun's disk is visible several weeks longer, and appears several weeks earlier, above the horizon, and also, both before its disappearance or its appearance, the twilight is so long that even at the pole the darkness of the night, which is very much lessened by the light of the long moonlight nights, continues only 13½ weeks. It may, therefore, be affirmed, as already mentioned, that the division of daylight and night is rather to the advantage of the polar regions, in comparison with the equatorial countries. But we justly connect with the word climate the prevailing degree of heat, and hold it for settled beforehand, that the region of the first climates (1 to 3) are the warmest, and that those of the last, the 22d to the 24th climate must be the coldest.

Thus the average temperature of the whole year is brought into consideration, which is not the medium between the greatest

summer's heat and the severest cold of winter, but is obtained from the sums of the degrees of heat, ascertained every day of the year by three daily observations. Although this average temperature of the whole year upon the surface of the earth at different seasons of the year, and indeed of every day, is subject to great changes, yet at a certain depth, in cellars and wells, and in most springs, both in summer and winter, there is a uniformity of heat, so that the temperature of the springs of a country can with a degree of certainty decide its annual average heat.

It is found in general that the annual average heat of the 3 first climates, from the equator to something beyond the tropics amounts to, from 77° F. to 82 5° F. At Cairo, situated in 30° 2′ N. L., the average temperature reaches only 72°; in Naples (41° N. L.) 64°; in Paris (48° 50′ N. L.) something over 53°; in London (51½° N. L.) 50°; in Copenhagen (55° 41′ N. L.) only a little over 45.5°; in Moscow (55¾° N. L.) only 40°; in Wadsoë (70½° N. L.) 35°. At the North Cape, although situated not a whole degree north of Wadsoë, the earth does not thaw at a depth of a few feet even in summer, the average temperature of the earth is the freezing point, (32°,) while at Melvill's island, it falls 2° below the freezing point.

Even on the ice and snowfields of the polar regions, at 80° L., there is observable at the season, when the sun does not set, a considerable influence exerted by its higher or lower position. Although still above the horizon at midnight, not only is its light very much paler than 12 hours before at midday, but the warming power of its rays is so much weaker, that when it descends towards the horizon, the snow, which had thawed when the sun stood higher, grows hard again. On which account the bold adventurers, who seek the north pole, avail themselves of the hours in summer, when it is night with us, to drag their sledge-boats over the driving ice-masses, and halt the longest

when it is about 7 or 8 A. M. by their watches, because about this time the ascending luminary acts the most powerfully to thaw the snow. Still more perceptible is the influence of a higher position of the sun, when we consider the relation, already referred to, of the average annual temperature of a country to its situation from the equator, where the sun every midday passes perpendicularly, or almost so, over the zenith, to the frigid zone, where it always remains far below the zenith. Nevertheless, only one general law affects this relation which is subject to manifold exceptions and variations. Only some of these, together with the causes that occasion them, will we here consider.

Even the artificial heat of our rooms rises in all parts of a chamber to a certain height, only when the walls, ceiling, and all the objects in the chamber have taken a certain degree of heat, and the temperature of the room, which corresponds to our feelings, continues when the fire is gradually diminished or wholly put out. A stove built after the Russian fashion, when its thick stone structure is thoroughly heated, communicates heat for hours after the fire is extinguished. In a similar way, as a collector and diffuser of Heat, does the surface of the earth act, especially the solid portion. The more the soil is warmed through by the sun's rays, the more powerfully does it give out heat, so long as it is kept at a certain degree of heat. For which reason the highest temperature of any one day does not, generally speaking, take place directly at midday, nor the greatest heat of the year on the longest day, and when the sun is the highest, but, in the first case, one or two hours after noon, and in the latter case, in the month of July. Just so, the lowest temperature of winter occurs generally in January, when the days have begun to lengthen; and the greatest cold of the day in the hours before sunrise. And further, the time at which, on an average, the greatest cold and the greatest

heat occurs, even in countries whose meridians lie not far from one another, is very different. In Paris the greatest cold generally occurs on the 17th, in Padua on the 15th, in Rome on the 17th, in Turin on the 3d of January; the greatest heat takes place in Paris, generally, on the 15th, in Padua on the 26th, in Turin the 27th of July, but in Rome about the 1st of August. Even between the tropics, the two-fold highest stand of the thermometer does not coincide with the highest position of the sun, when the day and night are exactly equal, but occurs on the 19th or 20th of April, and on the 22d or 23d of October; the time of the coolest days is the 19th or 20th January, and on the 22d or 23d of July. In the southern hemisphere also, the greatest heat of the summer comes after the sun has been at its highest point; thus at Capetown, the hottest day is the 2d February, the coldest the 6th July.

Not only the solid earth, even the water, which covers so great a part of the globe, and the air, which rests over it, are warmed by the sun's rays, although the elevation of their temperature is continually modified by the motion, already described. The atmosphere stands here in a two-fold relation to the earth's surface. While it weakens the power of the sun's rays, that must pass through it, it yet operates favorably to increase the heat of the earth, for, like a garment with which we protect ourselves from the cold, it affords some check to the radiation and dissipation of the heat, and unites in the warming process, going on from the earth's surface below, and the sun's influence above. But while the air near the earth is heated, it is also expanded, and thus becomes lighter; it ascends. In thus rising into regions, where the pressure of the air lessens in direct proportion to the height, the air, coming from below, becomes even rarer, occupies an increasing space, and by this rarefaction, the temperature is lowered, just as in the formation of steam; and this fact is shown in the falling temperature of surrounding

objects. But on the contrary, when in the place of the ascending heated layers of the air, the colder strata descend from the upper regions, then these volumes of air, through the pressure of the higher columns, suffer a condensation, and then, as always when an elastic fluid body is compressed into a narrow space, heat is generated and communicated to the surrounding world of matter.

Here is found, in part at least, the reason of the decrease of heat at great heights above the level of the sea. If we agree with *Schmidt*, that at a height of 334 feet above the sea coast, the average annual heat is about one degree lower, then in the region of Cairo, whose average annual temperature is over 70°, a mountain of the height of the *Finsteraarhorn*, in Switzerland, (13,205 ft.,) must have, at its top, a prevalent temperature, somewhat below that of North Cape, below the freezing point. Yet the decrease of heat, in ascending to great heights, is found to vary greatly, whether it be on a single mountain, or chains of mountains, or extensive highlands. On a mountain, standing by itself, at the same elevation above the level of the sea, a greater decrease of heat is observable than where the land forms a larger and a more extended mass. On which account, and for other reasons, the notion was a fallacious one, according to which a difference in the situation of places above the level of the sea, amounting to from 260 to 270 feet, was supposed to have the same influence on the average temperature of the year as the distance of a degree from the equator, so that the annual heat of a place lying at the level of the sea, in 50° L., must be equal to that found in the latitude of 40° at a height of about 2,600 feet. This idea was founded on the supposition, that the heat decreases regularly from one degree of latitude to another. But this is by no means the case, *for the* average temperature from the equator to 10° L., re*mains* almost exactly the same, from 10° to the northern tropic,

it amounts on the east coast of America, without decrease for every degree of latitude, in general to only $\frac{1}{6}$th, from the tropic to 33° L. to something more than $\frac{1}{2}$ of a degree (R.,) thence to 43° L. to near $\frac{4}{5}$ths of a degree of Reamur's scale, while, nearer to the pole it slowly increases again, until at last from beyond 79 to 80° L., the surface of the sea or of the solid land, is uniformly covered with constant ice or snow, so that there a degree of latitude, nearer to the pole or farther from it, hardly produces any perceptible difference of temperature. Middle Europe alone shows in regard to the decrease of the average temperature, a steady relation to geographical position, for here, as A. v. Humboldt states, from 38° to 71° L. the annual heat, for every degree of latitude falls about $\frac{2}{5}$ths of a degree of Reamur. The average temperature of the monastery of St. Bernard, which is at an elevation of 8,460 feet, must accordingly be that of 77° L. on the level.

Upon the decrease of heat, as we gradually rise above the level of the sea, depends especially the height of the limit of perpetual snow. It may be stated as a general fact that, in ascending a mountain under the equator, after those regions are passed, the temperature and vegetation of which correspond first to those of the temperate, and then of the frigid zone; at a height of from 15,000 to 17,000 ft. (the Cordilleras of Quito are almost 14,800, the Cordilleras of Chili, 17,260 ft.) the temperature is reached, beyond which the snow lies the year through; between the 42° and 43° L. on the Pyrenees, and on the Caucasus, those eminences are covered with continual snow, which are only about 8400 ft. high; in the Swiss Alps, (46° L.) the region of eternal snow reaches down to below 8200 ft.; in the Carpathian mountains (50° L.) snow is found all summer at a height of 7000 ft. The inhabitants of Norway in latitude 62° procure snow and ice at midsummer from *a height of 5000 ft.* Mountains only 2200 ft. high in 72° L.

are covered with snow the year through; and still nearer to the pole, the oblique rays of the sun do not melt the snow on the low hills, and it would remain unmelted on the tops of towers and lofty houses, if there were any buildings of that sort. Finally, we reach a point where sea and land are fast bound in perpetual frost.

The further descent of continual winter from the mountain heights downwards to the plains stands in no uniform relation to the distance from the equator, but depends, like the average temperature of countries, on quite other influences. The snow line retreats indeed, according to observations made in America, northwards from the equator, with the distance therefrom, so considerably, that in 19° L., in the highlands of Mexico, the snow line is about 960 ft. lower than on the Cordilleras of Quito; on the other hand it stands, as already mentioned, in Chili, where the mountains approach the sea to the westward, more than 2000 ft. higher than under the equator, although they lie in 16°—18° S. L. The most considerable exception to the apparent rule is found in the situation of the snow-line in the mountains of the Himalaya in 31° L. On the south, towards India, they reach the height of only 12,180 ft. which is only a little above one of the mountain peaks of the Tyrol; on the other hand, on the heights lying under almost the same degree of latitude and forming the northern declivity towards Thibet, the snow-line retreats to a height of 15,600 ft., so that on the northern sides the land is cultivated at a height which on the Indian descent is covered with perpetual snow. This fact, first stated by *Humboldt*, questioned by *Hutton*, but established by *Batten*, bears witness particularly to the power of the solid parts of the earth's surface in diffusing heat, for the high land of Thibet, to the north of the Himalaya, rises 10,800 ft., so that its heat, radiated from the sun, must have a great *effect* in driving back the snow-line upon the adjoining moun-

tains. The highland of Thibet enjoys so mild a temperature that around H'Lassa, 9000 ft. above the sea, the vine is cultivated, aided perhaps by the depth of the vallies.

Although, in comparing the annual temperature of different countries, we confine our attention only to the plains, or to slight elevations above the level of the sea, we meet with very remarkable exceptions to the rule, that the heat lessens in direct proportion to the distance from the equator. The first settlers in N. America, within the borders of what are now the United States, and travelers on the coasts of eastern Asia, were long ago struck with the fact, that, in both these quarters of the globe, the winter's cold is much severer, and even the summers on the whole were much cooler than in European countries lying in the same latitudes, or even more to the north. When, according to Humboldt, we compare the annual temperature of places on the eastern coast of America, with that of the same latitudes in Europe and northern Africa, we find, the more the distance from the equator increases, the more remarkable is the advantage in respect to mildness of climate, which Europe has over America. Nain, on the coast of Labrador is in 57° 8′ N. L. while Christiana in Norway is distant 59° 55′ from the equator, and yet at the former place the average temperature is 5.5° F. *below* the freezing point, while in Christiana it is nearly 10.7° F. *above* that point. The average temperature of Quebec amounts to only 42°, although it lies about 5½° south of Amsterdam, whose average temperature is nearly 52°. Halifax lies in the same latitude with Bordeaux, New York with Naples. But the average heat of the two American places is much lower than that of the European, that of Halifax more than 13°, that of N. York about 7° lower than the temperature of Naples. As we approach the equator, these differences gradually vanish, and in 30° N. L., St. Augustine and Cairo,

having the same geographical position, enjoy almost the same degree of warmth.

And not only in relation to the west coast of Europe, but also when compared with the west coast of the same part of the world, the eastern coast of America stands at a disadvantage in respect of mildness of climate. New Archangel or the west coast of N. America lies almost in the same latitude with Nain in Labrador, and yet the annual heat of the former exceeds that of the latter about 19°, for not only does the summer's heat in New Archangel rise 13° higher, but its winters also are milder. The same relation subsists between the west coast of Europe and the east coast of Asia. Pekin is somewhat south of Naples, yet its average temperature is more than 9° lower than that of Naples. The winter in Pekin is very severe, for the average temperature of the season is nearly 5° below the freezing point, the cold is consequently several degrees greater than at Copenhagen, which yet lies about 17° more to the north.

The vicinity of an ocean obviously has a moderating influence on the climate, and its effect is moreover considerable upon the temperature of the earth. Water, as a less susceptible conductor of heat, takes neither heat nor cold in the same degree with the solid land. Heat, even that, generated by the direct rays of the sun, is, besides, diminished by constant evaporation; the influence of the winter air is moderated, because the cooling of the water is communicated to its whole mass, to its lowest depths, and thus only gradually is a steady and low degree of temperature reached, while, at the same time it gives out but little heat by radiation. Further, the influence of the evaporation of the water of the ocean is more observable in the air, resting on its surface, than in the temperature of the surface of the water itself. The latter, from the equator to

48° N. and S. L., is found to be always somewhat higher than the neighboring strata of air. In all these ways the ocean tends to equalise temperatures; it moderates both the heat and the cold of the adjoining land, so that sea-coasts and islands suffer no such remarkable differences as the countries lying far from the ocean, in the interior of continents. Thus, as Humboldt remarks, some cities in the interior of northern Asia as Tobolsk, (58° 12′ N. L.,) Barnaul at Obi, (53° 19′ N. L.,) and Irkurtsk, (52° 17′), in regard to temperature, have just such summers as Berlin, (52° 31′), Munster, (51° 5.7′), and Cherbourg in Normandy, (49° 38′). In the first mentioned places, the thermometer stands for weeks sometimes at 86° and almost 88° F.; but these summers are followed by winters, when, for a month at a time, there prevails a temperature 2° to 4° below zero.

By the mildness of the winter, the average temperature of many places may be high, while their situation is not consequently favorable to the growth of those plants, for which they would seem to be fitted. In the north east of Ireland, in 54° 56′ N. L., of course in the same latitude with Könisberg in Prussia, the average temperature of the winter is almost 8° abve the freezing point, consequently higher than in Milan, Padua, and the whole of Lombardy, where the average stand of the thermometer in winter only rises about 4° above the freezing point. But although now, if this mildness of half the year were alone to decide the matter, Dublin in Ireland would have a yet milder climate than Milan, yet the apparent advantage is quite neutralized by the low temperature of the summer, which averages only 59° in such a region, almost always wrapt in mist. The average annual heat of Milan is 55°, that of Dublin not much over 46°. Ofen in Hungary affords an example of the contrary. There the winter is usually so cold, that its temperature falls to over 4° below the freezing point, consequently

more than 11° lower than in the above mentioned parts of Ireland; the average heat of the summer in Hungary rises over 68°, and even over 70° F. Still more striking is the contrast between the average temperatures of winter and summer at some points of the north-west coast of Europe. On the Orkneys, (e. g. Stromness,) not a half degree south of Stockholm, the winter is (according to Humboldt,) milder than at Paris, almost as mild as in London. Even on the Faroe islands, in 62° N. L., the waters of the interior never freeze. On the lovely coast of Devonshire, where the harbor of Salcombe has been called, on account of its mild climate, the Montpellier of the north, the American aloes (*Agave Americana*) is seen blooming in the open air, as in the south of France and Italy. There, and at Pozana and Gosport, and on the coasts of Normandy at Cherbourg, the average winter-temperature is over 42°, i. e. scarcely a degree below that of Montpellier and Florence. And yet we should err, if we should expect the same effects that follow the climate of Montpellier and Florence. While in the environs of London, the strawberry-tree and myrtle endure the winter, and bear their blossoms in the open air as freely as in the botanical gardens at Montpellier, while in Ireland also, the New Zealand flax can be raised in the open air, yet the vine never fully ripens its fruit, and the same is true of all those fruits which require a high and continuous heat, which, of course, must be accompanied by a certain mildness of winter, that the plants may not be destroyed by frost.

On both summer and winter, it is not merely the position of the sun that acts, but also the situation of a country in relation to the sea and other lands. The perpendicular rays of the sun at the equator and between the tropics, act much more powerfully upon the land than sea. From the land, especially when dry, stony, and without shade, like the African and Asiatic sand-deserts, there arise, when the sun is at its height, hot

streams of air, which pour themselves into the colder regions towards the poles, while heavier, colder air rushes in from the last named regions, and from above. The soil of the stony and sandy wastes between the tropics is not infrequently heated to 126°, and even more than 140° F. This last degree of heat was observed by *A. Humboldt*, in the white granite sand at the falls of the Orinoco, while the heat of the air scarcely amounted to 86°; on the other hand, *J. v. Roth*, the companion of Capt. *Harris*, on the English expedition to Schoa, saw in the stony desert in 9° L., the thermometer rise to nearly 124° in the shade. So great an excess of heat cannot, however, in proportion to the colder strata of the air of the upper and the polar regions long be kept up; ordinarily the nights, on such hot wastes, are sensibly cooler.

The line of the highest position of the sun, the tropic of Cancer, passes over land only a sixth part of the sun's course, the remaining $\frac{5}{6}$ths, it passes over water. That sixth falls almost entirely on those portions of Africa, over whose land masses the equator passes; also over some regions of the continent, and larger islands of Asia and Australia, the sun stands twice a year in the zenith, while only $\frac{3}{5}$ths of the land, lying under the equator belong to America. Herein lies a cause of that greater annual heat that distinguishes Europe for instance from the greatest part of the other countries. The streams of warm air, generated by the sun over the soil of Africa lying between the tropics, have, at some points, only a short space to pass over the Mediterranean, and where the Mediterranean is broader, it weakens the heating power of the south winds so little that they are felt as a hot Sirocco through all Italy up to the Tyrolese Alps. The westerly countries of Asia to the middle degree of latitude are warmed in the same way, and especially the East Indian peninsulas, with the large islands near them.

The directly opposite, cooling effect is produced by the air-currents coming from the polar regions, upon a continent that extends without interruption far up towards the pole. Europe is bounded on its most northerly coast by a sea, which, within the polar circle, is mostly free from ice, while the northernmost continent of Asia extends in part over the polar circle, and like the most northerly coast of America, is girdled by a sea which is only in part free from ice. Hence come those raw currents of air, which bring even to the winters in the more southerly regions of Siberia, a so high degree of cold.

From the rotation of the earth on its axis, points near the poles have a much less velocity than those at the equator. Hence the currents of air coming from the north towards the equator, having far less velocity than the swifter moving bodies at the equator, the latter are pushed against these currents, they become a constant wind in the direction contrary to that in which the earth revolves, that is, from east to west, or an east wind, (the trade winds.) The equilibrium of the columns of air, being thus disturbed, is restored by the west and south-west winds which prevail in the temperate zones the greater part of the year. When this predominating current of air passes over a broad expanse of water, before it reaches land, it shares the mild winter-temperature of the ocean, and imparts the same to the coasts over which it passes; when, on the contrary, it travels far over continents, it is so cooled by the wintry cold of the land, that it diminishes considerably the annual heat of the countries, which it traverses. Here is the main reason of the mild winters of the western coasts, and the harder winters of the eastern coasts of our continents.

But further, the ocean, as already remarked, effects an equalization of the temperatures of summer and winter, hence peninsulas, or bays running far into the land, and the existence of large inland seas, everywhere contribute to moderate

climate. The currents of the ocean, when they are of an elevated temperature, communicate to the countries, whose shores they wash, the advantage of an increase of warmth, as *Sabine* has shown in the case of the Gulf stream, which takes its course from the coast of Mexico, towards the west coasts of Africa and Europe. In all these respects, Europe and western Asia, bordering on the Mediterranean, the Black and the Caspian seas, appear to be especially adapted both to the comfort and well-being of their inhabitants and to the intercourse of nations; and almost the same advantages are enjoyed by the countries of southern Asia, situated on peninsulas and penetrated by long arms of the sea, and by several portions of central America.

A local influence of an opposite kind, tending to lessen the annual heat, is exercised, in the temperate and frigid zones, by swamps and shallow waters, covered in winter with ice that melts late in the spring, by the vicinity of high mountains, standing alone, from whose snowy peaks currents of cold air flow down, and by extensive forests, which, by the evaporation of the moisture they imbibe, and by shading the soil, keep it cool, and finally by the direction of long mountain chains, which obstruct the currents of warm air.

When we consider the expanse of the different zones, formed as they are by reference to the position of the sun and the prevailing annual heat, a very favorable fact is shown in regard to the earth's surface. The torrid zone, which stretches from the equator to the tropics, embraces a space of 77,700,000 square miles, each of the two temperate zones, from the tropics to the polar circles, 50 millions, both together 100 millions of miles, each of the inhospitable frigid zones only 8 millions square miles. Only for the eleventh part of the earth, therefore, is the power of the sun's rays too weak to dissipate in summer the ice and snow of winter.

At the two extremes, in the torrid and polar zones, in the same latitudes, the greatest agreement of average temperatures is found; when, on the other hand, we compare the annual heat of countries under equal parallels from the coasts of the Atlantic, from France through Germany, Poland and Russia, eastward to the Ural chain, we find it steadily decreasing. Beyond the Ural mountains, the mild west winds become cold land winds; the climate of western Siberia is subjected to all the disadvantageous influences, to which a continent far extended, with uniform steppes, and covered with salt lakes and swamps, is exposed. On the contrary, when we imagine, drawn over the surface of the globe, along side and between the lines that represent the degrees of latitude, other lines, indicating the equal degrees of the year's heat (isothermal lines) we find that such a line bends upward considerably, passing from the east coast of America to the west coast of Europe, inasmuch as at 70° L., the same average temperature is found on the European coast, that prevails on the American coast scarcely at 57° and 60°. But if we follow lines of the same sort from Lapland eastward towards Asia, we see them at once bend considerably downwards, so that in the farthest east of Asia in 57° 60° L., the average temperature does not stand higher than in northernmost Lapland. This isothermal line, however, again rises when we follow it across the Pacific to the western coast of N. America; the average temperature here approaches that which distinguishes places on the western coast of Europe, in the same latitudes. Upon these bendings of the isothermal lines, upon their depression below and their elevation above the lines of latitude, the direction of which they follow on the whole, an obvious influence is exerted, at many points, where they pass over oceans and islands or portions of land, by this variety in the forms of the earth's surface, so that *where an* isothermal line passes from the ocean or from small

islands through a long strip of land, or a larger island, an elevation or depression of the temperature, according to the circumstances mentioned above, takes place.

In some neighboring places even of one and the same continent, in places whose latitude is precisely the same, and which are at an equal height above the sea, a considerable difference of temperature is observable, when one place is situated on the declivity of a mountain, the other upon an extended, high plain. The latter site presents in the Cordilleras an increase of the annual heat of 2° to nearly 3½° F.

That, for centuries, the general average heat of our planet has suffered no perceptible change appears, not only from history, but even from the exact calculations of astronomers. Had the earth's heat decreased, there would have been a change also of those other and intimate relations of things, with which is connected the time of the earth's rotation on its axis, and the length of the day, which, however, has remained the same for ages. The decline in the temperature of single years, or even of series of years is as local as it is temporary, and while one quarter has an unusually severe winter, or suffers from long continued heat and drought, another experiences a damp warm winter, or its soil is flooded with rain. At this present time the northern hemisphere has an advantage over the southern, in that its midsummer coincides nearly with that time in its annual course, during which the earth is farthest from the sun; our midwinter, of course, according with the time when the sun is nearest. As, according to the law of universal gravity, or of the polaric relations between the central body and the bodies subordinated to it, the rate with which one of these bodies moves in its orbit increases as the square of the distance from the centre decreases, so is it the consequence of that coincidence of the two main points of the year with the different distances from the sun, that the winter half of the

year is almost 8 days (7 days 18 hours) shorter than the summer half, the latter being of course so much the longer. As, however, this relation is variable, inasmuch as the points in the earth's orbit, where the sun's greatest nearness and greatest distance, fall, (the perihelion and aphelion,) do not always remain the same, but advance annually about 61½' (almost the 29th part of the diameter of the moon's disk,) hence it follows: that the difference between the length of the summer and the winter, on both hemispheres, was not always the same, nor can it be. Already now the time of the perihelion no longer occurs precisely at the beginning of winter, but on the 1st of January, and the aphelion occurs after the middle of the summer half of the year, (after the summer solstice) not until the 3d of July, and about every 58 years, these points of time advance about one calendar day. If, therefore, we reckon back, it is found that almost 6000 years ago, the perihelion occurred at the beginning of autumn, the aphelion at the beginning of spring, and that then the two great divisions of the year were exactly of the same length in both hemispheres. But, therefore, at that time, the northern hemisphere was neither warmer nor colder than it is now. For besides that, as already stated, astronomy has proved, from the uniform rate of the daily revolution of the earth on its axis, that the average heat of the earth for ages has been the same, the revolution of the earth round the sun, or the year, has kept exactly the same length, the mean distance of the earth from its central body is still precisely the same as formerly. The illumination and warming of the solid land between the tropics, by the sun standing perpendicularly or almost so, has, on the whole, remained unchanged both in duration and power; the warm columns of air, ascending from the land, the ocean-currents, which, coming from the torrid zone north and south of the equator and washing the west and north-west shores of the eastern hemisphere,

are specially the same; the relation of the periodical equalizations of the heat of one region with the cold of another was the same thousands of years ago, and will be the same thousands of years hence that it is now. Even the increase and the decrease of the ice of the polar seas and of mountain tops is subject to certain limitations of alternate, periodical equalization. The advantage, which the northern hemisphere has over the southern, especially in respect of its warmer summers, is founded chiefly on the larger mass of land, existing in it. The predominating quantity of water on the southern hemisphere helps indeed to soften its winters, but it also gives occasion for the collection in the atmosphere of watery vapor, which impedes the access of the sun's rays to the earth, and delays the approaches of summer. In comparison with the polar land of the northern hemisphere, fearful, therefore, must be the situation of the lately discovered polar land of the south. The former is connected in part with continents from which warm air-currents may rise, without losing their temperature over the sea. But the southern polar land is cut off from these contributions of warm air by a broad ocean and by the ice which fills its waters.

Nevertheless, in the neighborhood of these cloud-wrapt, never thawing masses of ice, there yet stirs a world of microscopic animals, in such variety of kind, and in such countless numbers, that Capt. *Ross* brought home from his voyage to the south pole, under 78° 10' S. L., from pieces of floating ice over 15 species of these animals with their flinty shells. In some of these specimens the greenish ovaries left no doubt that these animals belonged not to a long dead, but to a yet living race, the inhabitants of the coldest zone of the earth.

But although this little throng of the animal kingdom, by the countless numbers in which it peoples the northern and southern polar zones, gives proof that, in the wintry gloom of those regions

as well as in the depths of the earth, life is possible, yet it is true only in relation to these imperfect forms of life. Other, higher animals, as Humboldt remarks, require, not only the influence of a higher, average heat, but also the clear, unclouded heaven, and the sun's light streaming down from a certain higher point. A mixture of chlorine and hydrogen does not take fire at the same temperature of the air, when the sky is overcast, and the sun's rays are somewhat weakened. It ignites with a violent explosion the instant the light breaks forth in full brightness from the atmosphere. Thus we find also that in many places, under a higher average annual temperature, the myrtle and laurel flourish in the open air, and yet many fruits will not ripen, because a clouded sky only rarely suffers the sunlight to break through, and the geographical position of such places is such that the sun's rays fall only obliquely. We are here led from the consideration of the sun's heat and its influence on the earth to the consideration of the light of the sun and its properties.

52. THE DAGUERREOTYPE AND PHOTOGRAPHY OR LIGHT-DRAWING.

We pause here, for a few moments, over one of the most remarkable discoveries of modern times, because it brings us acquainted with a property of light, by which it discloses its relationship to those electro-magnetic forces which we have already considered.

It was long ago known that the vibratory motion of sounding bodies, which is communicated as an audible sound to the air and so to the ear, possesses a certain power of producing forms. When a finely pulverised substance, such as rosin, is spread upon glass tablets, which give forth various tones by the drawing of a violin bow over their edges, it is observed that as

many figures are formed in the rosin as there are tones, by the vibrations of the glass, or of any bodies set in audible motion in a similar way. The vibrating motions, communicated to bodies by the electric and electro-magnetic currents, produce similar formations, and the difference between the forms, produced by positive and negative electricity, was early recognised. In light, and especially in the light of the sun, observation must early have discovered a coloring and fashioning agency. Those stunted, ugly-colored *Anomia*, (a species of bivalve muscle,) drawn up by ships anchors from a depth, to which only the weakest glimmer of light reaches, show us how animated bodies are dependant for their formation on daylight. The same influence of light appears also in the sprouts of potatoes, and other vegetables, which have attempted to germinate and grow in cellars and dark caverns. It is true, the crystalline formations of unorganised bodies do not appear to require the influence of light; it is of the utmost importance, however, to many chemical actions.

The sunlight acts with a decomposing power, especially on the combinations of gold and silver with different substances; these metals may be separated, by means of light, in a metallic form, or in a condition of imperfect oxydation. We have spoken of *Iodine*, which is obtained from the ashes of several sea-plants. It is mixed, besides, in minute quantities, with the water of various springs. This substance, insoluble in water, soluble in spirits of wine, of an almost metallic brightness, changing by heat into a violet blue colored gas, enters, like Chlorine and Bromine, (its fellow inhabitants of the sea and of sea-plants,) into combinations with silver, from which this metal is immediately separated by the influence of light. Upon the facility with which iodide of silver is decomposed rests the discovery made in the year 1839, by *Niepci* and *Daguerre*.

A copper plate is covered (plated) with silver, and carefully polished, in order to obtain as pure and smooth a surface as possible. It is then placed in the dark in a vessel, at the bottom of which is put iodine, which, by being heated from below, is converted into vapor, and in this form combines with the silver on the surface of the plate which then becomes of a light yellow color. As soon as this combination is completed, the metal plate with its fine covering of iodide of silver is immediately taken out and placed in a camera obscura in which the image of the object, illuminated by the sun, is formed by a lens in diminished proportions upon the metal plate, as upon any other surface, placed in the focus. In a few moments the light, passing from the illuminated body into the camera obscura, and upon the iodide of silver, acts upon this composition: the silver is separated from the iodine. But still, when the plate is drawn quickly out, (before the weaker light of the surrounding air has exerted its decomposing influence,) not a trace of a picture is discernible on its surface, but it becomes visible when the plate is taken from the camera obscura, and placed for some moments in a dark box, filled with the vapor rising from mercury heated to 149 or 158 degrees, which in this form unites with the silver, which is disengaged from the iodine by the effect of the light. There now remains nothing to be done but to get rid of the thin film, consisting of iodide of silver undecomposed, in order to prevent the further action of light upon the plate. This is done by dipping the plate in a solution of hypo-sulphite of soda in water, or in a boiling hot solution of common salt, the iodine thus quitting the silver and uniting with the soda. The plate is then washed in perfectly pure, distilled water. The quicksilver amalgam formed in the places where the silver has separated from the iodine, is unaffected by the weak hypo-sulphite of soda solution, or the boil-

ing salt water. This amalgam stands now, raised upon the bright silver plate, forming the lights of the picture, and the silver, cleansed wholly from the iodine, reflects light so perfectly as to appear dark, thus forming the shades, and the picture is done.

This method, first employed and thus described by the inventor of Photography, may be varied in different ways, by using, instead of iodine in a solid form, a solution of the same, diluted with water, in spirits of wine; to get rid of the iodide of silver covering, a cold solution of common salt suffices, if the plate, which is dipped into the solution, be touched by a small rod of zinc, and the chemical action be accelerated by galvanic influence. The sensibility of the silver solution to the influence of light may be still further increased by the use of a combination of iodine and chlorine, instead of pure iodine, or by adding a portion of bromine to the solution, or by holding the plate, when the formation of the iodide of silver film is completed, for some moments, over a weak solution of chlorine, by which its yellowish color becomes red. By means of these improvements has it become possible to seize the swiftly flitting spectacle of the visible world, and fix it as a picture.

Instead of plates, covered with silver, paper is also used, wet in a weak solution of nitrate of silver, (1⅔ drams to 12 oz. of water) then dried, next dipped into a watery solution of iodide of potassium, and finally drawn through water, and again dried. The paper is kept from the light; just before it is used, a mixture of nitrate of silver with ⅛th of acetic acid and a saturated solution of gallic acid are spread over it. After the paper thus prepared has been exposed for a short time in the camera obscura to the action of light, the above mentioned mixture is again spread over it, it is gently heated, and finally a solution of bromide of potassium is applied to it, to fix the limits of the picture. It is true, what is dark in the object

represented is light in the light-drawing, and the reverse, but this is avoided by laying the light-drawing between two glass plates upon another paper, prepared in the same way, and exposing both to the action of the sunlight. For then the light shining through the light places of the light-drawing, produces on the paper beneath it that decomposition, by which the dark colored silver comes out, and where the darker places of the light-drawing are, bright spots appear, according to the greater or less opacity of the same. In this way, copies of drawings and copperplates may be produced by doubling the paper. But the preparation, as well as the use of the paper, called by Talbot, its inventor, kalotype, is attended by much greater difficulties than the employment of the metal plates, covered with silver, according to Daguerre's method, and is less exact.

It is indeed marvelous what can be done by the invention of the Daguerreotype, this simple combination of a camera obscura, and a metal plate covered with a tincture of iodide of silver. The traveler, whose way lies through a country never represented by human hand, while he rests in the shade of a rock or tree, has only to let the image of the landscape, illuminated by the sun, fall upon his Daguerreotype plate in a camera obscura, or he may direct his apparatus to a masterpiece of ancient architecture, and he has a copy of the landscape or the edifice, with the fidelity of which to the minutest particular, the art of man can enter into no rivalry. To obtain copies of the inscriptions, scarcely legible and as yet undeciphered, which are found on the sites of ancient ruins, formerly required hours and days of learned labor; they may now be prepared at once by the method of Daguerre. The hieroglyphics on obelisks or pillars of stone, the epitaphs inscribed on marble, may all now be copied in a few seconds with an exactness, which leaves nothing to be desired. The man of science, traveling in the luxuriant regions of the torrid zone, and meet-

ing with a multitude of animals never before seen, may, in an hour's time, obtain numerous drawings of their outward form, and internal structure.

It is indispensable, in order that the outlines of the light-drawing should be well defined, that the object represented should, at least for some seconds, keep its position unchanged. The waving motion of a flag in the open air makes it impossible to represent such an object distinctly; the object continually changing its place and form, the drawing is rendered indistinct. Yet even in this respect, since an increased sensibility to light has been given to the metallic mixture, what seemed impossible has become practicable. The present writer has seen a metal plate, on which was a drawing made by a photographer of Vienna, at the moment when the emperor Ferdinand made a grand entry into Lintz. Not only the buildings and all other fixed objects, but the people looking out of the windows, the immense throng in the streets were represented with the greatest distinctness. Had there been a near acquaintance in the crowd at the moment when the sunlight fell upon it, and the reflection fell upon the Daguerreotype, he could easily have been recognised in the drawing.

The light-drawings of the Daguerreotype certainly want the charm of color. These pictures are only in black and white. Even with this defect, the forming power of light, through decomposition thus revealed to us is most wonderful. This action of light may be likened in a manner to the imagination and memory in the living soul. A light-ray of that Universal Intelligence, evidently divine, falls into the darkness of our understanding, is caught by this (as the silver by the mercury, united with it,) and thus comes to be an enduring property of our nature.

53. THE PRISM.

Before we proceed to speak further of the properties of light, let us refer to a fact universally known: the separation of the sun's ray into several bright colors, when it passes, under the due conditions, through a transparent three-sided rod of ground glass, (the prism,) and falls upon a wall, or any reflecting surface. The color-picture or spectrum, which under these circumstances, becomes visible, is essentially, although on a small scale, a repetition of the splendid spectacle of the rainbow. Both phenomena have their origin in a separation of the sun's light in consequence of the refraction which it suffers in passing through a transparent body.

The refraction thus undergone by the rays of light, is different from ordinary refraction. Were a perfectly even plate of glass, of the same thickness as the prism, placed in a little, window-like opening, that opens out of an otherwise darkened room into the open daylight, it would, (in proportion to its size,) serve the same purpose as a window. As we looked out through it at the sun, we should see the sun's disk in its natural, round form, and the light, coming in through this opening, would appear on the wall opposite in the same form with this little window. But if, instead of a glass plate, we hold a three-sided prism before this opening in a horizontal position, so that one edge is turned towards the floor, the light falls upon one surface of the prism, and takes its way through the transparent glass towards the opposite surface. But as, in this direction, the prism is not of equal thickness, but below, where the two surfaces terminate in the sharp edge, it is much narrower than above, where it spreads out towards the third surface, the rays of light have to take below a shorter, and above a longer way through the different diameters of the three-sided glass medium.

They accordingly suffer a very different refraction, the lower rays being less, and the upper rays more, refracted. On this stronger or weaker refraction depends, not only the direction which the ray takes when it emerges on the other side of the transparent body, but also the measure of illuminating power, which the light, after passing through the glass, still retains. For even the most transparent body takes from the light that passes through it a portion of its illuminating power; the thicker it is, the more it diminishes the power of the light, water consequently more than air, and glass still more than water. The form of the light, therefore, thrown by a prism, held as above, on the opposite wall, appears, not only on account of the different degrees of refraction, oblongated from above downwards, but parts of the spectrum are of various degrees of light, the upper part, which is most refracted, being the faintest, the lower part the brightest. Herewith a remarkable change takes place in the appearance of the light. It is no longer the colorless light of day, but it is separated into different strips of different color, not indeed sharply defined, but one color melting at its edges into another. The colors from below upwards (or in the rainbow from above downwards) are in the following order, first red, over red, orange, then yellow, green, blue, and lastly, at the top, violet, or if, with Newton we distinguish seven colors, the blue is followed by indigo blue, and then follows the violet. Of all the colors the violet is the least bright, next in weakness is the blue, the yellow gives the strongest light, and the orange exceeds the light of the green and red rays.

But the activity of the rays is not confined to the limits of the different colors; it extends beyond into the light and colorless vicinity of the spectrum. When a daguerreotype plate, or even the most carefully prepared photographic paper, is exposed to the rays of a prism, it is observed that the red ray

has no activity; the paper and the plate remain unaffected. The yellow ray also manifests scarcely a trace of chemical influence; only at the edge of the blue does such an influence begin to be perceptible, and it is stronger in the blue itself, and still more in the violet, and even beyond the violet, at a point where no color and no light are visible. We attributed the decomposition, which the iodide of silver in our daguerreotype apparatus undergoes, to the light, and to the common light of day, and presumed, of course, that, where the light is greatest, its chemical activity is strongest. But we are here taught the contrary, for not only is the violet ray, whose light is the weakest, most powerful in its chemical influence, but a light still weaker, invisible to us, shows itself most active, chemically regarded. This appears also from the influence of the prismatic colors on other chemical processes. A mixture of dry chlorine gas and hydrogen, which undergoes no change when kept in the dark, remains unchanged when exposed to the red and the yellow rays, its conversion into muriatic acid takes place gradually, as in ordinary daylight, when it is submitted to the blueish green, but the change is sudden when the violet ray falls on it.

In connection with the influence of the different colors of the prism, may be mentioned, in passing, the insensibility of the daguerreotype plates and of photographic paper to the green color of foliage, which, on this account, even when immovable, is at best only imperfectly represented in light drawings.

Not only the chemical power but the warming property of light is found to reside at one end of the spectrum, and even beyond the limits of the same. But it is the red ray, not the violet, that gives the greatest heat. When a piece of thin paper is blackened on one side by a weak, smoky flame, and spread with this blackened side upon a board, and the white side is wet with strong spirits of wine, and the spectrum is

allowed to fall on it, it may be plainly seen that the paper dries the quickest under the red ray, and the slowest under the violet, and that of course, the greatest heat must be in the former. Among all transparent bodies, the crystalline, water-clear, rock salt allows heat to pass through the least diminished, without reflecting it or retaining any perceptible degree of it to raise the temperature of its own mass. When the form of a three-sided prism is given to a piece of this mineral salt, we obtain by it not only a perfect spectrum, but are also able to mark the difference between the heating and non-heating portion of the light. By a delicate thermometer one may be convinced that the temperature under the violet ray remains undisturbed, while it rises as we approach the red ray. And even under the red ray the heat is not so great as beyond it, at a distance from the border of the red, equal to a third of the whole length of the spectrum. Consequently the light manifests its activity, and most strikingly, where to our eyes no light is perceptible.

54. THE MOON AND ITS LIGHT.

The consideration of the warming property of the sun's light leads us to that of the non-warming quality of that luminary which, next to the sun, is the most important to our planet. Along with the apparent revolutions of the sun, the course and place of the moon afford the inhabitants of the earth the means of dividing and determining time. The long enduring darkness of the polar zone, in winter, is, in some degree, alleviated by the steady shining of the moon; and with us also, and even in the most highly favored climate of the warmer zones, the mild light of the moon gives to the night a special charm. In those lands, whose skies, almost always clear, are

much more transparent than ours, the moonlight is so bright that we may read by it without difficulty. Yet it is calculated, and, by direct admeasurement of the strength of the light, ascertained, that the light of the moon is 800,000 times weaker than that of the sun. The light of the moon is only the reflection of the sun's light, which must certainly find upon the moon's surface a substance highly capable of reflection, for the moon's light is like the brightness of a snowy mountain-top, or glacier seen from a distance.

If the surface of the moon were of a whitish stone similar to our limestone, one would think that we here on the earth must feel something of the heat of the sun's reflected light. But the moonlight communicates no perceptible heat to the earth, and even a thermometer, placed in the focus of the most powerful burning glass or reflecting mirror, shows no measurable increase of heat. One might, indeed, almost be inclined to attach weight to certain, as yet indeed only isolated observations of Lichtenberg's, and consider the moon a cold-diffusing body. When this celebrated philosopher observed with special attention the average temperature of those days on which our earth in the path of its orbit occupied the exact place where the moon had been a few hours before, he found that once (in June) it was a time of unusual cold, and another time, in autumn, that the weather was very stormy. Nevertheless, since the use of such instruments for the measuring of heat as have been described in the chapter on the importance of heat to magnetism and electricity, it has been ascertained that the light of the moon is not wholly without the power of producing heat.

The light of the moon, as well as that of the sun, may be separated in a similar way into the colors of the rainbow, although the colors are a great deal weaker; the pale, scarcely

distinguishable red and the violet of the lunar rainbow and of the spectrum, cast by the prism, are as little capable of chemical influence as of producing heat.

The whole character of the moon, so far as the telescope brings us acquainted with it, gives us no great idea either of its heat or of its power to communicate the same. On our earth, water discharges the beneficent office of equalizing the extremes of temperature; the warmer currents flowing towards the northern hemisphere from the south and southwest, and at the north, from the north and northwest, carry a portion of their heat to regions remote from the equator; and at the same time the heat of the tropics is moderated by the currents of cool air from the colder zones. What a useful covering our atmosphere forms for our planet, so that it does not lose by radiation the heat received from the sun, is seen from the cold, prevailing at those heights where the air is rare, and by the cold of those nights in the winter and early spring when the sky is cloudless, and no warm air-current from the south prevents the temperature's falling. In enumerating the advantages which our fair earth has over the moon, if we wish to go any further, we may note the no inconsiderable fact, that, with the exception of the polar zones, in all climates, in the short space of 24 hours, the sun rises and sets once, once midnight alternates with midday, and the inhabitants of the temperate zones, the most numerous among the denizens of the earth, and the most vigorous in body and mind, experience every year the wholesome influence of the changes of the seasons.

What a quite different lot, in these respects, is appointed to the companion of our earth, the moon! There there is neither sea nor wind, no morning nor evening red, but according to our measure of time, every month has a summer of 14 days, when the sun, mounting to the zenith of the equator, or descending to the lower position at the polar regions, neither

rises nor sets once, and then follows just as long a winter night. Were there upon the moon an ocean, or a sea of the size of one of our inland seas, it would have been distinguished by the telescope, but though art has multiplied the power of our vision a thousand fold, nothing meets the eye in the moon but a mass of heights and depths, mountains rising high above the measure of our Alps and Cordilleras, and abysmal cavities, so broad and deep that a Mount Blanc or Chimborasso would hardly suffice to fill them. Not only is there no sea, not a drop of water exists on the moon. If a single stream flowed there, or if springs gushed from the declivities of mountains as with us, then here and there those fearful caverns would have been filled; water, if it existed there, or even the snow, would have risen in vapor under the influence of the sun, and formed an atmosphere round the moon, which, although it originated on the other side of the moon, would immediately, by the law of gravity, be diffused over all parts of the surface of the moon. Such an atmosphere would be visible to us through the telescope, not only by its changes arising from changes of temperature, but also by other consequences of the refraction of light; were there any kind of atmosphere, like ours, there would be at least a brief twilight; but the latest observations have discovered nothing of the kind. The idea of a very rare atmosphere around the moon, lacks confirmation. The poor moon, in a higher degree almost, than a mountain 8 or 9 miles high on the earth would be, is exposed without protection to the sun's rays during its long day, and to the escape of the heat during its equally long night.

The heavens as seen from the moon are of course clear enough, never overcast by cloud or mist, no storms rage there, but one day is like another—and what profound silence reigns there on that little neighboring world!

Aye indeed, a stillness like that of the grave, the deep, unbroken stillness of nature. There no bird sings, no flute, nor organ nor Æolian harp sounds; air is wanting for music as for breathing. When in ascending a lofty mountain, or in mounting in a balloon, we reach a region, in which there is still air, but very much rarefied, the strongest tone of the human voice sounds like a faint, muffled noise; even the discharge of a musket is inaudible at the distance of a few hundred feet. But where there is no atmosphere whatever, the fall of a mountain could be perceived only by the shaking of the solid ground; the corpse, buried deep in the grave, would be more sensible of it than the erect, living man. And with the ear, the eye also, and all the senses, were they like ours, would suffer the consequences of the absence of air, for without air there would be no flame here on the earth, without oxygen gas and its access to the oxydisable metals, or to a combustible element, there would be no green of the plant or the emerald, no red on the cheek or of the ruby, no decorative colors of blossoms or insects, indeed, with few exceptions, no colored stone. If water and air were withdrawn, our earth would have neither animals nor plants, nor even a particle of mould, in which the seed might germinate and unfold; the mountains would not indeed crumble by the action of air or water, but naked and dry they would, like a bleached skeleton, reflect the sunlight.

But we may spare ourselves the vain endeavor of portraying the moon in the colors which our human understanding furnishes us with. These colors are like those which we let fall through a prism upon a heap of baker's flour. In the light of these colors the wholesome flour appears as a strange mass of red, yellow, blue and violet dust, whose conversion into bread would be beyond the scope of our imagination. We lay aside the prism and lo! the brightly colored dust is nothing but a well known, useful meal. Our human judgment separates the

light of knowledge that falls within the circle of its comprehension, into the colored rays of its own sensuous experience; and these colors do as little belong to the real nature of the objects which we contemplate as the coloring thrown by the prism on the flour. Before the investigations of travelers had disclosed it, who could have surmised the existence of that immeasurable fulness of animalcula rejoicing in life in the icy masses and the never-melting snow of the polar region? Although we can conjecture but little, and know with certainty still less of the moon, one thing we know, that that heavenly body, with all that is thereon and therein, is made the care of the same creative power, which everywhere generates motion and vital activity, because it is itself Life. That there on the white, field of death, as it appears, of the moon's surface, transformations and vicissitudes of decay and birth are going on, seems to be the case even from some observations of science. But to what purposes and for whom those cavernous depths, so frightful to our eyes, are there, by which the surface of the moon is broken; upon what beings falls the blinding brilliancy of the sun, and the pale ash-gray light, that comes from the huge disk of the earth, standing immovable in one place in the moon's sky—these things, so long as we are bound to this terrestrial world, we can never know.

55. THE RELATION OF LIGHT TO COLORS.

The sunlight, so it is understood, is divided by the prism into rays of different colors, because it is composed of these colors, for the prismatic colors, as the oft repeated experiments of Newton seem to teach, make the impression of white light, when collected into one. It is customary to prove this, by giving a swift swinging motion to the prism, which is communicated to the spectrum, and causes the separate rays of the same

to flow together in so plain a manner, that they appear together only as a white, clear, strip of light. In a lens, the several colors of the prismatic figure unite so completely that no colors, only the clear common light of day is perceived.

The reflected sunlight, which from the illuminated disk of one of the planets, especially of Venus and Mars, falls into a prism, produces a spectrum, similar to that of the rays of the sun. In the spectrum, caused by the flame of a burning body, several colors are generally visible, but sometimes one color prevails so that the others are scarcely distinguishable. When alcohol is much diluted, it burns with a yellowish light; the same color predominates in the spectrum, and the same appearance is presented in the case of bodies imperfectly combustible. Even in the spectrum of a common taper, when its light falls upon the prism through a narrow slit, there appears, between the red and yellow, a light strip, which intimates the predominance of yellow. On the other hand, when phosphorus is burnt with saltpetre, a spectrum is produced, in which no single color prevails; and the same is true of the light given out by platinum at a white heat, and other heated substances.

A remarkable phenomena, in the light of the spectrum, into which light is decomposed by the prism, is presented in those dark, partly black lines often seen by the naked eye, when, instead of falling on the wall, the spectrum is caught at the proper distance from the prism, but still better, when the spectrum is examined through a telescope. Of whatever transparent substance the prism is made, these lines always appear in proportionally equal strength, and in the same order; the magnifying power of the telescope is of considerable importance to the distinctness of the phenomenon. In the red, the smallest lines comparatively are seen, although still tolerably distinct; in the green is found the blackest line of all, in the blue, several, and among them one line composed of many

fine lines. The number of fine lines, among which is one, composed of many crowded lines, increases towards and in the indigo blue; in the violet, follow several times, at longer intervals two broad stripes, very striking, and standing at a little distance from one another; then come four groups of lines, in the first and second of which only three, then five lines can be plainly distinguished. Many of the lines which appear single from an ordinary telescope, are seen with a more powerful instrument, to consist of several lines; *Fraunhofer* counted nearly 600.

Although this phenomenon, to which Fraunhofer, in Munich, first drew attention, may signify but little, and even the way, in which it has been explained, may not be satisfactory, it is still worthy the most careful consideration, as it promises some explanation of the variety in the sun-like light of the fixed stars. In the light of Sirius, for instance, three broad stripes are seen, of which two are in the blue, and one is in the green, and the same is the case with the spectrum of Castor. But in the spectrum of Pollux, as in that of the sun, a great number of very delicate lines is discerned; in Procyon only a few. Instead of these dark lines in the spectrum of the sun and several of the fixed stars, many bright lines appear in the spectrum of the electric spark, the number and arrangement of which differ with the metals from which the spark is drawn.

In every respect it appears worthy of note that even in the centre of light, the brightest we know, the light of the sun, there is still found an alternation of light and darkness, increase and decrease. This alternation, this rising and falling, is the common characteristic of all nature and its forces.

The colors existing in the light are distributed in manifold gradations and mixtures, one with another, in terrestrial bodies. Where they are connected with the quality of transparency, the daylight shows the same effect which is observed in the ray

of the prismatic spectrum. Thus the chloride of silver quickly grows black when subjected to light passing through a violet colored glass, while it remains unchanged under a red light, or takes merely a rosy hue, (as by heat.)

In the colors, presented in the terrestrial world, we remark a great difference in respect to reflecting the light and heat which they receive. Black is the perfect opposite of light and all its colors; it is the entire absence of both. All the more powerfully does the attraction of the opposite show itself. It takes the light that falls on it, without reflecting it, it is, therefore, more powerfully affected by the heat of the sun's rays. When several pieces of cloth of the same web and size, but of different colors, are laid in the snow and exposed to the light, the snow under the black cloth melts soonest and most, and under the white it thaws the least. Next to black cloth, the dark brown and the blood red (blackish red) show the greatest power of receiving and communicating heat.

This property of black to promote heat by light has given occasion to the invention of a photometer, (light-measurer,) the use of which has indeed been superseded by other instruments, that fulfil its main purpose better,—it is still, however, valuable as making evident the heat-giving power of light. Two thermometers are chosen for the experiment, which rise and fall exactly alike; when the ball of one of them is blackened, and so long as both are kept in the dark, they indicate the external temperature in the same way, but as soon as the light is let in, the mercury or spirits of wine in the thermometer with a blackened ball instantly rises higher than the other. This difference becomes greater, the stronger the light. *Leslie* made this experiment, which *Pictet* had first tried in order to measure the light of the sun in comparison with that of an ordinary flame. He found that in causing the mercury in a blackened thermometer to rise, the light of the sun is 12,000

times more powerful than that of a candle, so that a portion of the sun's disk, of the size of a taper, radiated a degree of heat equal to that of 12,000 wax candles. Other observations have, however, taught that the rays of a fire, in proportion to their illuminating power, give much less heat than the rays of the sun, but that, at the same time, the heat of a fire is more quickly consumed, in raising the temperature of transparent bodies, through which its light passes, than the heat of the sun, on which account when the rays of a flame are collected in a burning glass, the latter is made warm; but while the light at its focus has a greatly increased brightness, it produces only a very slight heat. On the other hand, when, for the same experiment, a burning glass is used, of so dark a color that it lets no rays of light through, (is non-transparent,) the heat at the focus is increased greatly; so that it would seem that, in the first case, the warming power of the flame is consumed and left in the glass, while its illuminating power passes without obstruction through the glass, and, in the other case, that the reverse is the fact.

We will mention here, only in passing, that other mode which has come into more general use, of estimating the light which a luminous body gives; a method based very simply upon the strength of the shadow which a metallic rod for instance throws on a white ground. If one wishes to compare the light of two such bodies, he has only to let the shadows of the rod, caused by their light, to fall upon a white ground, and if, for example, one light proceeds from a plate of platinum, at a white heat, and the other from a wax candle, both lights must be placed at such distances that both shadows are equally dark. In comparing the light of the sun with any other light, a little glass ball filled with mercury may be used, on which a ray of the sun's light is allowed to fall, and then the strength of the reflected ray of sunlight is compared with that of a wax

candle, for instance, by observing the former through a telescope, and the latter through a convex lens, and then adjusting the distances until both lights are equally bright. In this, and various other ways, the light emitted by luminous bodies has been so nicely determined, that it has been found that 5,563 wax lights are, at the distance of 1 foot, equal to the light of the sun. The light of Sirius is 20,000 millions of times weaker than that of the sun, and nine times greater than that of Vega, in the Lyre. The light of the moon is calculated to be about 25,000 (24,966) times greater than that of Sirius, although it would take 800,000 moons to diffuse over the earth the light of midday. As the earth is at the same distance from the sun with the moon, we may measure the light, which, as a star among the stars, it irradiates as well from those parts of its surface most favorable to reflection, as from the ocean, allowance being made for the effects of the density of the atmosphere on this reflection. It is found that, in proportion to their size, Mercury reflects a light $6\frac{2}{3}$, Venus a light twice as great as that of the earth; while the planetary light of Mars is only $\frac{4}{5}$ths as bright. When further, the light of the remotest planets is compared with that which they should reflect according to their distance from the sun, if they are physically like our earth, it is found that the light of the farthest planets is greater than calculation fixes it. These bodies, therefore, must have some peculiar power of producing light, besides that which they receive from the sun. Without such power, which is probably accompanied also with a peculiar power of generating heat, those remote suburbs of the solar system must be quite uninhabitable for beings like us.

Let us turn, however, again to the color-giving power of light. Not only the colors of the prism, but also what we ordinarily name colors, the coloring substances with which our garments, pictures, glass vessels, and other works of art, are

rendered pleasing to the eye, are all children of the light, and show in all their stages their entire dependence on light.

When those two most common combustible substances, carbon and hydrogen gas, are burnt with oxygen, the light of the flame is not only specially bright, but the new combinations, carbonic acid and water, are also transparent and clear, without any decided color. When on the other hand, we mix with these more complete combustibles other substances of a metallic or earthy nature, which impede the process of combustion, the flame shows those bright colors which we give to our fireworks. A little addition of pulverized strontia in spirits of wine gives to the flame a bright purple red colour. The addition of such a substance, obstructing the process, acts here in the same way with the prism, when the prism comes with its weakening and diverting influence between the sunlight and the body to be illuminated.

The color which we thus give to the flame, is a transient appearance, it can however, according to the nature of the substance which combines with the oxygen, undergo a sort of combustion, become more or less fixed. The production of the metallic oxyde resembles, according to its nature, a species of combustion; but it stands to ordinary combustion, which is attended with flame, as the gentle, imperceptible passing to and fro of electricity between the earth and the atmosphere, to the lightning of the thunder-cloud. That inner, vibrating motion, which produces on the eye the effect of light and color, becomes, in imperfect combustion or oxydation, particularly of the metals, a continuous and steady motion, and is communicated in this state to transparent, solid bodies. On which account the beautiful green of oxyde of chromium has shone forth with unchangeable power from the emerald for thousands of years, and its red, from the ruby, and the green of oxyde of nickel from the chrysoprase. It is the oxydes of iron which

in most instances give to stones and even to organized natures, their great variety of colors, such as red in its different shades, and yellow, green, blue and violet. And it is to be remarked that oftentimes the bright colors, communicated by a metallic element to transparent bodies at different stages of its imperfect saturation with oxygen, disappear and become white when the saturation (or, as it were, combustion) is complete. The same is the case with carbon, when in its imperfect combustion it presents those dark colors which we often see in its mixture with other bodies, for when converted into carbonic acid, it has the waterlike clearness of the gases. Here is the cause of that effect, which an admixture of manganese ore has in destroying the colors of our glass which is colored sometimes by iron, in one state of oxydation; the oxygen gas, which this ore has so abundantly, is used up in this process in saturating the imperfectly oxydized coloring substances; they become clear and colorless, and the pure molten silica of glass, and mountain crystals even, are so also.

In organic nature we often see the whole process reversed. The leaves of a plant, which puts forth in a warm, dark cellar, do not have the natural green color, but are a pale white, but expose them to the sunlight, they soon become of a fresh green. The effect of the sun upon the leaves of plants is to disengage their oxygen. The carbon of carbonic acid is hereby put into a state of imperfect oxydation, and instantly becomes colored. The more powerful the development of the vital activity of the plant is, the more actively and steadily does the disengagement of its oxygen go on. And this may be the reason why the young leaves of the plant give litmus paper a reddish color, like a weak acid.

The peculiar, green-coloring substance of plants resembles in many of its qualities the resins; carbon, and with carbon, hydrogen take a predominant part in its chemical composition. The

vegetable green dissolves just like the resins, not in water, but in alcohol, and still more readily in oils, but preserves its color in this solution only while kept from the light; directly the sun shines on it, it become first brown then white. This decolorising influence shows itself on the green tincture, extracted by means of alcohol from cherry and elder leaves, in the space of 20 minutes. On the contrary, indigo, which is obtained from the leaves of the indigo plant, is white so long as oxygen has no access to it, but when it is exposed to the air, it eagerly attracts the oxygen, and becomes blue. Upon the coloring substances, obtained from the vegetable world, the light, especially that of the direct rays of the sun, has a powerful influence, changing, and at last destroying their colors. Even a high degree of heat can produce such changes. Many vegetable colors, which are only slowly decolorised by the sun, are bleached in a few minutes, when exposed to a current of air heated to the boiling point. The yellow color, given to paper by the tincture of *Quaja*, when put under the violet ray of the prism is changed into green by imbibing oxygen, but it is restored by a moderate degree of heat.

As colors have a very obvious influence on the inanimate world, they affect animated beings in a still higher degree. Apart from the chemical action of the violet ray on the vitality of the vegetable leaf, a preference for, or an antipathy to, certain colors is manifested by many animals. A tame crane, which was long observed by *H. v. Schauroth*, showed the greatest dislike of some other domestic animals, obviously because they were black; for to other animals of the same species, which were of a different color, he manifested no such antipathy. Red is known to exert an almost maddening influence upon some animals. Cows of a red color, are continually exposed in our Alpine herds to the persecutions of their companions, so that they have to be kept apart. It is dangerous to approach

the horned cattle on the Alps in a red dress; even a red cloth will irritate them to attack the unconscious stranger. To our turkies, particularly of American origin, red is an object of terror, they will assault it, when they feel themselves equal to the conflict. We read in the account of *Valentine Duval*, what an effect a red rag, hung around the neck of a young turkeycock, had upon the poor animal, an effect, which, but for a good providence, would have had just as sad consequences for the herdsboy as for his feathered nursling. In the south of France, turkies are governed, not by a whip or staff, but by a stick with a piece of scarlet cloth fastened to the end. In this way whole flocks are driven to market.

Even on the temper of man, the prevailing colors that surround him, exercise perhaps a greater influence than, amidst the distractions of daily life, he is aware of. The nations of antiquity have said and fabled much in regard to the influence of colors and the brilliancy of precious stones. We need not their authority to say, much less to believe, that the sight of the beautiful violet-colored amethyst inspires pleasant dreamings; the brilliancy of the diamond or the ruby may give valor and firmness to the soldier in battle, or the mild green light of the emerald may compose the passions. The foliage of trees soothes the spirit. By gazing long on a yellow color, the mind may be affected with disgust. Red, according to its degree of mixture with yellow or blue, or its perfect purity in carmine, may have an influence on the affections. In the pure white of the lily, there lies that which appears akin to the serene activity and life of the soul.

56. THE PHOSPHORESCENCE OF BODIES.

We would gladly establish for so sublime an element as Light, and even for Heat also, agents, so wide and so penetra-

ting in their power, the well-deserved glory of exerting no transitory influence. The bell, when struck by the hammer, continues to sound on audibly, and long after we cease to hear it, the vibrations of the metal, which the stroke of the hammer has produced, may still continue. So also the influence of Light still operates, in its coloring and illuminating properties, when the sun which radiated it has set, the flame, which generated it, is extinguished.

How astonished was that shoemaker in Bologna, *Vincent Cascariolo*, when he saw those stones, which he had heated, several hours before, in his cooking stove, still glowing red, although the fire had long been extinguished, and the stove and the shining stones were quite cold! It was not indeed any kind of stone that would have exhibited to him this remarkable appearance, but only that ash-gray, sulphurous spar which he chanced to pick up on Mount Paterno, near Bologna. Neither would every shoemaker, or indeed every scholar of those times, have made the curious discovery which Vincent made in regard to the so-called Bolognese light-stone. And had any distinguished man been led to it under the same circumstances with our Bolognese shoemaker, he would have been ashamed perhaps to tell the simple truth. But that was by no means the case with Vincent Cascariolo. He confessed, and all his neighbors knew, that his desire "to make gold," prompted him to the first experiment with this stone. It was only too well known that the man, instead of laboring industriously to support himself by his trade, gave himself up day and night to the longing to find "the substance of all substances," the "*prima materia*, of which the Creator made all things, and particularly gold, which man might imitate the dear God in making, if he only had that original substance in his possession." The earning of kreuzer by kreuzer, seemed to him altogether too trifling—"*gold* guilders, thousands upon thousands, and to-morrow

again thousands, with five holidays every week, with feasting and merry-makings—that sounded much better." But this good sound, which rung continually in his reveries in his ears, for a long while deluded Vincent, and was bringing him only want and care, when one day, (in the year 1630,) he picked up on Mt. Paterno, a gray stone, shaped like a flattened ball, with its surface glittering here and there, and observed that it was heavier than other stones. Immediately his beloved substance of substances occurred to him. Perhaps he had got it now in this stone, so he thought. He filled his pockets, went home, and kindled a good fire in his little alchemistical furnace, heated and roasted the stone, which yielded indeed no *prima materia*, but proved to be a curiosity with which the lover of natural science has loved to please his eyes from that day to this. For the fragments of the Bononian or Bolognese light stone, (as it is called from the place where it was first found,) continue to give out a colored light like the glow-warm in the dark, not only after being subjected to fire, but also when exposed for some moments to the sun.

Cascariolo made some profit even in money from his discovery, as he not only communicated it to the most distinguished men of science in his native city, but the friends of science throughout Italy and in other countries, spared no expense in obtaining a specimen of this remarkable stone. But the profit was much greater that Science itself drew from the knowledge of the fact that, without any sort of combustion, the motion which is in light, is communicated to a solid body, and continues for a time those vibrations which appear to us as a shining.

The diamond, indestructibly solid as it appears, yet consisting of pure carbon, is a combustible body. But every one knows what an extraordinary degree of heat, either in the focus of a burning mirror, or in the greatest power of a melting

furnace, is required to ignite this costly fuel, which yet, in burning, gives out no clear flame, but is decomposed with only an emission of sparks. But many diamonds, (the experiment does not succeed in all cases,) when exposed for the time to the sunlight, and then carried into the dark, continue to sparkle as if they were heated red hot. Near Nertschinsk, in Siberia, a variety of fluor spar is found, (called chlorophane) which possesses in a very high degree the property of shining in the dark, upon being previously exposed to the light; and our native fluorspar has the same quality, more or less. The Bologna lightstone consists, as has been said, of a combination of barytes with sulphuric acid, and on this combination rests mainly its quality of continuous shining. On which account our common heavy spar, (sulphate of barytes,) which is found in many parts, even of Germany, presents the same phenomenon as the Bologna stone, which is found, moreover, not only at Bologna, but near Amberg, in Bavaria, and in other places. And not only the heavy spar, but the sulphate of strontia, and a number of simple and compound bodies possess the property of continuing to shine when carried into the dark. Beyond all others, the most readily prepared is the Cantonian phosphorus (so styled from its inventor, *John Canton*, an Englishman,) which is made by roasting oyster shells, and then pulverizing them, and after mixing with them a fourth of their weight of flowers of sulphur, exposing them again for an hour in a crucible to a strong heat. A still better mixture, more sensitive to the light, is burnt oyster shells and suphuret of antimony. There are a number of natural and artificial substances which possess the property of the Bologna stone, which can be still better prepared for the experiment by being pulverized and mixed with gum tragacanth, and formed into little plates, and then heated for an hour.

Were our sense of sight, as sensitive to weaker degrees of ght as that of many animals, we should probably perceive a ght given forth in the dark by many species of rocks and stones at have been shone upon during the day, as was observed by *harpentier* in the case of several specimens of granite and eiss. And not only solid bodies, but the fluid element of the a, when illuminated during the day by a tropical sun, gives rth at night a light, which is not wholly of animal origin. ven in the German lakes, a weak phosphorescence has been bserved.

In old times, marvellous stories were told, which had their rigin in the east, the land of the sun, of a wonderful stone, he carbuncle, that gave light of itself, as bright as that of a aper, illuminating the darkness of subterranean caverns and aults. These stories were fabulous of course, but they had a oundation in truth, as the diamond and other precious stones stify.

In regard to all bodies which continue to give in the dark e light which they have received, it is to be remarked that is quality is shown by means of the light of the sun or any rning body, but not the light of the moon. Noteworthy also the fact, that the violet ray is chiefly favorable to this pro-rty, while it instantly ceases to be manifested, when the minous substance is exposed to the red ray of the spectrum.

With the species of illumination which we have here de-ribed and which is caused by a continuance of the vibrations undulations produced in bodies by light, we must not con-und that light which is the consequence of a slow combina-n with oxygen, or which is, in its sphere, like the electric ark, the indication of an equalizing (discharge) of the electric id, between the atmosphere and the earth. To phenomena this sort, belong those fire rains, the terrors of which affect sense but the eye. A distinguished and trustworthy man

of science, *T. Bergmann*, saw two such fire showers in September 1759, the heavy drops of which, when they fell upon the earth, gave out a strong spark, so that in the darkness of the night the fields had the appearance of being covered with a faintly shining fluid fire. It is hardly necessary to add, that this fire neither diffused heat nor possessed any destructive power.

Rotten wood, putrid flesh and fish, shine in the dark, but manifest no heat. This light is connected with a sort of slow combustion. When these phosphorescent substances are exposed to those gases, in which a candle goes out, they also cease to be luminous. Even many living animals, marine animalcula, (sea blubber) shine at night. In the glow-worm and fire-fly, the light they give is dependent upon the vital power and will of the insect, as in the case of the electric eel. A similar connection of a phosphorescent power with the will of the animal has been observed in the eyes of the cat.

57. CONJECTURES IN REGARD TO THE MATERIAL NATURE OF LIGHT.

From the remotest times, no visible object has more powerfully excited the activity of human thought than light. The question concerning the nature of light, Science has sought to answer in two ways. Either, so it has been thought, light is a subtile material fluid, continually emanating from the sun, and diffused through space, repelled (reflected) when it strikes a non-translucent body; or it consists in a vibrating motion, excited by the sun and all luminous bodies, and communicated to the ether, and propagated to our optic nerve, and to every other body susceptible of illumination. The first theory is designated as the theory of emanation, the latter as the undulatory theory.

The first philosopher known, who fashioned the idea of the efflux of light as a material fluid into a system was, so much we know, *Empedocles*, who lived in the middle of the 5th century before Christ, at Agrigentum, a city in Sicily, a spot where man might rejoice in the light and its brilliancy as in few other parts of the earth. For this Agrigentum, which in its palmiest days, held a population of 800,000 souls, contained everything that could delight the eye, and even now the traveler may spend a whole day and night in visiting the magnificent ruins of the old city, which like a jewel set in gold, lies in an uncommonly beautiful country. Scarcely any where else as there, does one feel that the eye is never satisfied with seeing. It is no strange thing, therefore, that the deep-thinking *Empedocles* took such pains to apprehend the subtile nature of the light, in a land where the light loves to linger, and where it awakens only pleasure in every genial human heart.

Twenty-one hundred years afterwards, as great a philosopher as Empedocles, the illustrious Englishman, *Isaac Newton*, elaborated the doctrine that light is a material emanation, with great acuteness.

The doctrine which regards light as a material emanation was opposed by one of the acutest thinkers of all times, *Aristotle*, in the 4th century before Christ. He expressed the opinion, which just two thousand years later was maintained with great power by a kindred genius, *Huygens*, a native of Holland, and by a German mathematician, *Euler*, namely, that light is an all-penetrating motion, not a substance, but a power belonging to substances, (undulation.) This theory has been so confirmed by the profound investigations of modern times that it may now be regarded as the prevailing one in this department of Physics.

Sound is communicated by a sounding body to the ear, because the air takes part in the vibratory motion into which that

body is thrown. Although no other terrestrial body is so penetrable to the light, so transparent, as the air, yet it cannot be the air, which communicates the undulations excited by a luminous body to other objects or to the eye. While sound is destroyed in a vacuum, a diamond or any reflecting body, shines just as clearly as in the air. The light comes to us from the sun and stars through spaces, in which nothing like our air is to be found. If it be held that motion can be communicated by one body to another at a distance, only through a material medium, the motion of which at one end produces a like motion at the other, as in the case of a row of billiard balls, we must then suppose the existence of a substance or fluid diffused throughout space, which is designated by the comprehensive nature of *Ether*. Everywhere present like gravitation, which, however, is no substance, but only a force penetrating all bodies, the ether must, in the celestial spaces, and in the transparent crystal and the solid diamond, in the human eye and the optic nerve, in the gases when they combine and ignite, and in every flame, be ceaselessly capable of an undulating motion, transmitted apparently in a straight direction from one part of the ether to another. In the sun and the sun-like fixed stars, a constant excitement of the vibrations of the etherial medium must be going on, an excitement, which from immeasurable distances is felt as Light.

We have just said that the undulatory motion of light is propagated in an *apparently* straight direction, for, that it is apparently and only apparently straight has been ascertained by the exact observations of recent times. A better and more distinct acquaintance with a phenomenon, which was formerly known by the name of the bending of the light, has afforded an explanation of this point, satisfactory to most. When the light is let into a darkened room through a small opening or *crack in* a window shutter, falling upon an upright piece of

wire, (a knitting-needle will serve the purpose,) this fine, opaque body does not cast a uniform, dark shadow upon a screen,—a shadow, the breadth of which is exactly proportioned to the distance of the screen and the opening whence the light comes, as one would expect upon the supposition that light is propagated in straight lines, but the shadow is much broader than it should be, according to the calculation, and exactly in the centre, where, according to the doctrine of the straight line radiation, there should be the greatest darkness, a bright stripe appears, bounded on both sides by dark lines, several of which are perceived, when the screen stands near the wire, but when it is removed farther off, only two lines are visible, and outside of them certain colored edges. The latter indeed become really visible only by means of a magnifying glass. By the same means, and by looking towards the wire, the whole phenomenon can be seen, without the screen, in the air; the shadow then appears as a number of equi-distant dark lines separated by fine, clear stripes. Around the circumference of the shadow of broader bodies, as, for instance, of small disks, when the light falls upon them in the same way, colored edges are visible, and, on a large scale around the shadows cast by the moon, in the case of total eclipses of that luminary.

The experiment has been tried in other ways, first proposed by *Fraunhofer*. The light which passes into a dark room through one narrow slit is examined with a telescope through a second narrow slit, which is made, perhaps in a screen, in a straight line with the first and at some distance from it. There is then seen a light, running through the middle of a clear white stripe, just as long as the slit, through which the light enters, but its breadth increases, the narrower the crevice through which the observer looks. On each side of this clear middle light, are seen three prismatic spectra, in the two of these which border on the light to the right and left of the light,

all the colors of the prism (the violet the inmost) are visible, while in the two remaining spectra the violet is wanting so that the indigo blue on each of them adjoins the red ray of the spectrum next to it. In the two outermost spectra, with the violet rays, the blue also are wanting, so that here they commence with the green rays. The innermost spectrum is besides the most distinct, the outermost the faintest, and the whole belt of light, white in the centre, and three colored, towards the sides becomes broader, the narrower the crevice in the screen is, through which the eye is directed.

The explanation of this phenomena could hardly be given with any completeness without mathematical signs. It must suffice to say that through the narrow opening, waves of light pass, not only in straight parallel lines, but also in other lines, of which those, that have to take paths of equal length from the sides of the opening, coinciding in the centre, are strengthened in their illuminating power, while the other rays, falling in at both sides of the centre, must take paths to the point of their meeting, which are of unequal length. But here now, the same thing happens that may be remarked in the case of musical strings, and indeed of any fluid, parts of which are put at the same time in unequal motions. When a current of air, uniform in direction and force, rushes into the flute-like sounding holes of a certain instrument which bears the name in physics, of Siren, and which is made to sound by being rapidly turned, a tone is heard, clear and distinct; but if the vibration is caused by two currents of air, different in direction and power, then, on account of the difference in the rapidity of the vibration, which they produce at the same time, their effect is neutralised; no tone whatever is heard. The experiment may be varied so that, in one case, two tones, e. g. octaves, in the other, only one is heard, while the other is inaudible. The case may be illustrated in very different ways with tubes, which

are made to sound by means of a plate set vibrating, accordingly as the mouth of the tube is submitted to one or another, up or down, more or less vibrating point of the plate.

In similar ways it has been attempted to explain a fact with which sailors must have become acquainted at sea from experience, namely, that the waves of the sea, when violently agitated, are quieted by oil poured upon them. The same interference produces in the two fluids, unequal as they are in weight and cohesion of parts, unequal undulations which mutually neutralise one another.

Thus from the hint caught from the phenomena of the so called bending of light, observed two centuries ago by *Grimaldi*, the conclusion has been drawn that rays of light meeting from paths of unequal lengths, like unequal audible vibrations, mutually neutralise one another, and thus become invisible; while parallel rays strengthen each other. We see therefore only the latter; with the others, and with their mutual neutralisation, we obtain some acquaintance by means of such contrivances as have been described.

Science comprehends this whole class of phenomena, by the observation of which the theory of undulation is confirmed, under the name of the *interference of the rays of light*, and one may speak of the interference of light and sound, and of all vibratory motions in the material world.

These phenomena have led the men of science of our time to take a bold step beyond what is required to explain and confirm the theory of undulation. They have undertaken to estimate the number of vibrations of the light within a given time. Were this as easily done as in the case of sound, the attempt would not appear so bold. For, to count the vibrations of sound, it is only necessary to stretch an elastic steel rod, with one end fastened by a screw, and set it vibrating

pendulum-fashion, at the other end. When the vibrations are counted, so far as they are distinguishable in a long rod, it is easy to see that a rod of the same character in other respects, but half the length, makes 4 times as many vibrations, a third rod, one third the length, 9 times as many vibrations as the long rod. The rapidity of the succession of the motion increases thus in inverse ratio to the square of the length. In like manner going backward, by exact observation of the length of a steel rod, whose vibrations give indeed an audible sound but are not distinguishable to the eye, one may ascertain the number of vibrations in a second, using rods of ever-increasing lengths, until at last the vibrations may be seen and counted. Thus in stretched strings the number of vibrations may be found out. In this case it is known, that, if the vibratory motion remains the same, but the length of the string is shortened about one half, the number of vibrations is doubled, and the same is true of organ pipes. Considering this as settled, it is calculated that the lowest note which the ear can perceive consists of 16 vibrations in a second. (Chladni adopts just double this number.) This low note corresponds to that produced by an organ pipe, 32 feet long and open at both ends. With every octave the number of vibrations doubles. The note of the highest string of our modern pianos consists of 3072 vibrations.

We come now to see how the undulations of light may be calculated by the analogy of vibrations of sound. We must imagine how sound is transmitted to the ear through the air—by a succession of waves, (when greater, longer, and when smaller, shorter also.) Sound travels 1120 Paris feet in a second. When at this distance we perceive the deepest tone of a 32 foot organ pipe, which makes 16 vibrations in a second, then every wave of sound which is excited by this tone must

be equal in length to the 16th part of 1120, i. e. to 70 feet, while the wave of the highest distinguishable notes is only a few lines, hardly even a line in length.

Immense as is the difference in speed of sound and light, must be the difference also in the number of the vibrations made by one and the other in a second. Fraunhofer measured the length of the undulations caused by the different colored rays of the prism, by hundred thousandths of a Paris inch. It is by such minute measures that Science has achieved her problem in regard to the undulations of light, and determined that the number of undulations made by the light of the sun is not less than 576 billions in a second. According to Sir J. Herschell's calculations, the undulations of the red ray of the prism are less in number and of the violet ray, greater; so that the red ray is found to correspond to the lowest, the violet to the highest note of an octave.

Thus has human intelligence here, as everywhere, passed beyond the limits of that knowledge which is obtained by the direct instrumentality of the senses, and entered upon a world which is discerned not visibly but by the spirit. Although the termination of its path does not always fall within the circle of clear, sensuous knowledge, although we often remain in uncertainty, whether an end has been reached, we are nevertheless assured that the impelling force which urges the mind on this career, dwells ineradicably in our nature.

58. INWORKING AND AFTERWORKING.

A large bell, on which the hammer has just struck the hour, sounds so loud, that it may be heard through a wide circle. But when it ceases to be heard at a distance of a few hundred steps, a person standing close to the tower, still hears the sound, and when even to this person it ceases to be audible,

a third individual, stationed on the tower, near the bell, still perceives the tone. The vibrations produced by an external impulse, may continue long after our sense of hearing has lost every trace of them; to organs of greater sensibility they would still be perceptible; as the track of the game is to the scent of the hound, when the game has wholly vanished from our sight.

When two voices sing together, the sound is of course louder than that of only one voice, and ten voices are louder than two. A room that has already been warmed is more speedily and effectually heated than a room which is heated for the first time. So the greater susceptibility which any body has for a particular motion, produced by an external impulse, appears often to depend upon the fact, that the motion which the body has previously received, has not wholly ceased, but is continued as a sort of echo, and therefore contributes essentially to a new motion.

This remark is particularly illustrated by those phenomena, addressed to the most discriminating of our senses, the sense of sight. The diamond, by means of friction, not only manifests a more or less electrical light, but, through the light of the sun or of a candle, receives the power of shining, for some time afterwards, in the dark. All diamonds are not capable of this power; and it has been remarked, that those diamonds that give out no light after friction, show no phosphorescent quality in the dark, after being exposed to the sun's rays. But when two diamonds of this latter kind have been struck powerfully together, they not only both give light, but they obtain the power of becoming luminous in the dark through friction, and by means of sun light. With a finely polished diamond, the experiment has been made, of rendering it self-luminous by repeated strokes of a file. For two days the experiment seemed *fruitless;* only on the third day did the first signs of a phos-

phorescence become manifest, but these signs became more apparent, and were called forth with increasing facility, so that not only was the phenomenon of light produced by a piece of wood instead of a file, but the light of the sun had the effect of showing a property of shining in the diamond, of which it previously appeared incapable.

That motion in the interior of a material body, still going on after it had ceased to be perceptible to our senses, is sometimes styled, in popular speech, "disposition," (*Stimmung.*) Essentially, the magnetic power, produced in a steel rod by continuous strokes of a hammer in the same direction, and the crystalline arrangement of the parts of a body, caused in a similar way by mechanical means, is to be denominated such a disposition. The friends and masters of stringed instruments of music, especially of the violin, know, not only that the repeated agitation of a steel rod by a hammer generates in the same a magnetic disposition of a certain harmonious character, but that there may be generated in a violin also, the symphonious wood-work of which is often set vibrating in harmony by means of the vibrations of the strings, a musical disposition, or temper, nay, that in every string, in every bell of an harmonica, such a musical tendency may be awakened, founded on the continuance of that vibrating motion, which the musician has called forth repeatedly in the strings or the bells.

When a crystal is formed out of a liquid or gaseous solution, it appears to be complete; the arrangement of the several parts of this little magnet, with their attracting and repelling ends, seems to be finished. But this is by no means the case. As those who are hard of hearing quicken their dulled sense by a hearing-tube, so, with our art, we can bring those motions, which were active in the formation of the crystal, and which, so long as it remains in this form, continue—we can bring them anew within the sphere of our observation, by putting the

crystal, which seemed to be finished, into a solution of such substances as are fitted to promote crystallisation. The oxyde of chromium, mixed in a certain proportion with sulphuric acid, and with an alkali and parts of the water in which, along with it, these substances were dissolved, forms, when the water is evaporating, dark green, eight-sided crystals. When these crystals, after being formed and kept dry for years, are placed in a watery solution of common alum, the crystallising movement immediately commences, and goes on where it had previously been compelled to come to a still-stand through want of material. The regularly shooting particles of the alum place themselves, one by another and over another, on the already formed surfaces of the octohedron, which resumes its previously interrupted growth, like a living vegetable, to which after long languishing, water is again given for its nourishment. There arise eight-sided crystals, which, in their interior present a dark green nucleus of the same form around which, as a capsule, the common transparent alum salt has deposited itself. Centuries, nay, milleniums do not weaken this power of resuming the motion originally active in the formation of the crystal. The masses which fill up the rifts of mountains may have been formed at periods very far remote from one another. Crystals, from solutions of a later period, have, however, been deposited, on the surfaces or ledges of crystals formed long before, in an order, which shows plainly that the motion, which was active at the formation of the crystal upon which the deposit is made, was still working on it. We known not how many thousands of years ago, the beautiful green or yellow was formed in the six-sided crystals of fluor spar in the ore-veins of our primitive mountains. It was taken perhaps a century ago out of the depths of the earth, and has since lain under glass in a mineralogical cabinet. But its power of growing, and in a certain *form*, has by no means forsaken it, as it soon shows, when we

place it in a solution of muriate of lime, just taken perhaps from the waters of the Dead Sea. As the water evaporates, its surface immediately begin to grow in due form, not, indeed, with the same color, or the same hardness or brilliancy, but with the same shape. In the same way the crystal of sulphate of lime, (selenite,) formed, it is true, quite otherwise than fluor spar, continues its growth, when brought into contact with sulphate of magnesia when in process of crystallisation.

There have been found in the coffins of the Egyptian mummies, and in the shrivelled hands of the dead, the dried up shrunken bulbs of garlic, and similar vegetables, and the ripe kernels and ears of grain. Several thousands of years ago, were these bulbs or kernals deposited with the embalmed corpses in the tombs, and during this long time their power to germinate and grow has not been destroyed; placed in a rich damp soil, they have sprung up and yielded a rich increase. The same has proved to be the case with seeds, which have lain hidden for centuries under the stones and foundations of old buildings.

Even on a grand scale, in whole masses of mountain rock, a continued working on may be observed of that internal motion, which caused their original formation. A distinguished traveler and excellent miner, *Russegger*, has made on this subject some very interesting observations, to which he was led by his mining investigations on Mt. Taurus. From the character and form of certain mountain strata in that region, together with the form and position in which the ore-masses, containing lime stone, are there found, it may be plainly seen that attracting forces have wrought and globular formations been carried on for long periods after their beginning. In the motion of such a continuous formation, only one kind, not all the rocks took part, so that the layers of stone, in the midst of which these foreign components pursued the work of mutual combination, fell thereby into a state of disorder, which plainly

shows, that the process of the continued formation of the ore-deposites took place at a time when they had already assumed their perfect solid form. Thus many other substances forming stone, as for instance, the silica has carried on the work of mutual attraction and arrangement of parts in a lime stone mountain already formed. There, especially where exists any cavity or vacant space in the interior of the mountains, the strange substances, dwelling scattered therein, form associations with others, barytes with barytes, sulphuret of lead with other lead of its kind, oxyde of iron, or sulphuret of iron with its like. There are ties similar to those of blood or friendship among men, which exist, in their peculiar way, even in the realms of dead substances, by which the scattered forces of many individuals, united in a common agency, may receive the all forming, all upholding influence of the universal Life.

59. PATERNAL AND MATERNAL INFLUENCE UPON THE FORMATION AND ACTIVITY OF NEWLY FORMED BODIES.

As of a maternal, forming character may that influence be regarded which the character of the elements has upon the form of a forming crystal. That this influence is very important and decisive, soon becomes obvious. For wherever silica can crytallize, be it in the depths of the earth or on the heights of mountains, in the vicinity of the pole or between the tropics, it always takes a form derived from that primitive form which lies at the foundation of its doubled six-sided pyramids, united with the six-sided column proceeding from its corners or edges.

In the case of crystals, composed of a great number of substances, the form remains the same, even when, instead of one substance, another enters into the formation, the particles of which possess the power of entering into the same polaric relation, which is the basis of the regular arrangement of parts;

a similar relation, perhaps, to that which may be seen in a chain made of little magnetic iron bars, when one of these bars is taken out, and a bar of nickel of the same size is put in its place, the north pole of which has just such an attraction for the south pole of the nearest iron bar, as the bar taken out. For the same reason, the form of the granite, ordinarily composed of silica, clay and oxyde of iron, remains the same, when instead of clay, lime; instead of lime, magnesia, instead of oxyde of iron, oxyde of manganese has taken part on the combination. Those substances, of which, one can take the place of another, without producing any change in the effect of the internal forming influence, are termed isomorphous; and most lucidly has this whole process been illustrated by *Justus Leibig*, in his chemical letters.

But the same eminent writer has called attention to another very considerable influence in the formation of crystals, the peculiar effect of which is not determined by the character of the component parts, and which, in opposition to the elementary or maternal influence may be distinguished as a paternal power. In this way, independently of chemical aid, heat, light and electricity, and other kindred physical forces act upon the peculiar direction of crystallisation.

One of the best known among the examples which might be mentioned here, is afforded us in two kinds of stone of the carbonite of lime species: in arragonite and common calcareous spar. The first, found particularly in Arragon, and formed in six-sided columns, mostly of a dingy amethyst color, in gmpsum, is distinguished essentially from common calcareous spar, by greater hardness and a greater specific gravity. When the common crystallised carbonate of lime, e. g. Iceland spar, is perfectly transparent, it is remarkable for its power of double refraction, i. e. letters, lines, and other objects, seen through it, appear not single but double. In the transparent arragonite

(from Bohemia, &c.) this kind of refraction is wanting. The essential form, which its crystals take, is quite different from that to which the manifold forms of calcareous spar may be traced, which may be broken into simply square fragments. In this entire difference between these two kinds of stone, the character of the chemical constituents has no share, for upon the most careful analysis, the lime is found in both, united in the same proportion with the carbonic acid. But what the constituents would not do, that is effected by the influence of heat. For if carbonate of lime is permitted to crystallise from a solution in cold water, the crystals present the form and all the other qualities of common calcareous spar, but, if warm water is used, the crystals become arragonite. But yet once again, and indeed in an wholly opposite way, the elevation of the temperature shows its fashioning influence on this remarkable stone. When a crystal of arragonite is exposed to a weak heat, all its parts fall into lively motion; it swells out to a foaming blister-like form, and is converted into a heap of little crystals which are nothing but common calcareous spar.

Something quite similar is seen in sulphur, which, at a low temperature, shows crystals of a rhomboid, eight-sided shape, but, in crystallising from a melted state, takes a very different form. In the same way, copper crystallising under a melting heat, and sulphate of zinc under a higher temperature, take forms very different from the ordinary ones, and the same is true of magnesia and arsenious acid; and sulphate of nickel, under three different degrees of temperature, presents a threefold variety of form.

When, to mention an instance nearer at hand, common salt is made to crystallise in its solution in water by the evaporation or cooling of the dissolving liquid, it takes the form of a cube, or the kindred eight-sided figure (octohedron,) or even the *squa*re twelve-sided shape, in both which the cube is the funda-

mental form. Yet this occurs only when the cooling of the fluid does not reach the freezing point. When, on the other hand, a saturated solution of common salt is exposed to the winter's frost or to an artificial cold even of only 22° below the freezing point, there are produced, instead of cube-shaped crystals, large, beautiful columns, as clear and transparent as water, belonging to quite a different family of crystals from the cube. At the slightest touch of the finger, these clear crystals became milk-white and opaque, and, when laid in the palm of a warm hand, they melt into a thick liquid, in which little common salt crystals of the ordinary cube form, are generated. To this remarkable change of form, which takes place also in the salt, consisting of chlorine and sodium, the temperature has obviously contributed most essentially, although this influence has also the effect to cause a combination with the chloride of sodium, of a considerable quantity of water, (about 30 per cent,) which, in the mixture of common, cube-shaped crystalline salt, is wholly wanting.

Of cases of this sort, in which one and the same substance, one and the same mixture of elements appears in quite different form and character, and thereby indicates a difference in the paternal influence, active on the formation of the body, there are still several, for of this kind are especially those stone-like or metallic fossils, which were represented as dimorphous.

But not only in the inorganic combinations of substances, but also in those produced by the force of organic life, the forming influence of heat and light is manifest. The white of a hen's egg is, in its ordinary state, fluid, soluble in water, and at a tolerably high temperature, transparent; but when exposed to a heat of 167°, and more, it becomes white like porcelain, it loses its fluidity and transparency, and its solubility in water. The roots of the manihot plant, growing in hot coun-

tries, are, in their raw state, not only unpalatable, but even poisonous; but when subjected to heat, when roasted in hot ashes, they become not only pleasant in taste, but a wholesome article of food, (tapioca or cassava.) What useful changes the potato undergoes when roasted or boiled, we all know. It is such a change that we communicate to most vegetables. When the people inhabiting the high land of Persia have made a dough or a broth, by mixing with water the meal of the edible acorns, which they obtain by grinding the dried fruit between two stones, they have a very agreeable nutritious article of food which may be kept several days, without undergoing fermentation or any injurious change. The whole provision, which one of these people takes with him for a foot journey of several weeks, consists in such a dough of acorn-meal, which he carries in a leathern bottle. If we wished to keep a dough of our meal for several days in as warm an air as that of middle Persia, without any addition of yeast or leaven, there would soon commence a fermentation, which is delayed in the acorn-meal by the astringent substance contained in it. But even when our dough is fermenting, or is made to ferment by our artificial additions, and has thereby become wholly unpalatable, we give it, by means of heat, that quality which renders it a pleasant means of nourishment, which may be kept for a long time, as ship bread.

The fermentation of grape juice and the souring of milk we can likewise prevent by a boiling heat, and both may be kept some time from fermenting, by being repeatedly boiled down. By this increase of temperature, however, we can only interrupt or delay the fermentation of these fluids, which is renewed by the continued access of the air, in the moderate temperature of our climate. The flesh of animals, the rapid decomposition of which is prevented by roasting, for the same reason tends again to decay. Hence the application of boiling

heat to articles of food in order to preserve them only first became really useful when *Gay Lussac*, in a very simple way, taught European cooks how meat, with vegetables and all kinds of sweet fruits, may be so cooked and prepared, that, after the lapse of a year, they are as fresh as if cooked only a few hours before; consequently they can be carried and used in the deserts of Africa or on distant seas. This was an invention which for its usefulness and simplicity, appeared worthy of so distinguished a philosopher. Now in every house it has become possible to obtain for the next winter or the next year, just when they are best, the fine vegetables of the garden, the flesh of young fowls, or other perishable viands of food. It would even be possible, by Gay Lussac's method, to entertain the guests at the bridal of a granddaughter with a dish of which the guests at the wedding of her grandmother partook. But apart from this method on a small scale, by which the aged and the sick may be provided at all seasons of the year with young fresh peas or beans, not from the hot-houses of the rich, but from their own little gardens, the utility of this invention, on a large scale, is worthy of attention. Those huge cooking institutions, for instance, in Scotland and in France, which daily prepare vast quantities of the most nutritious soups, vegetables and roasted and boiled meats for hundreds, not of guests at home, but of guests at remote distances,—these institutions, just as they provision ships and whole fleets and even caravans traveling in remote countries, could also furnish garrisons for years with wholesome food. Starvation, and the danger of disease from unhealthy nourishment is averted, in all such cases, on land and water.

As we have considered somewhat at length so many of those inventions, which are adapted to promote the subsistence and intercourse of nations, Gay Lussac's plan may claim here to be briefly described. Meat or vegetables are first cooked as

thoroughly as if designed for immediate use. Then while still hot, they are put in tin boxes, and the boxes are packed full. When this is done, the covers of the same material are soldered down, and the boxes made air-tight. But they are not yet prepared to be sent over land and sea, or to be kept for years. The nicely closed boxes are placed in a large kettle of boiling water, and here in proportion to their size, subjected for hours to a boiling heat, so that the whole may be thoroughly penetrated with the heat.

In the case of carbonate of lime and chloride of sodium or common salt, and many other substances, susceptible of crystallisation, the paternal influence of heat operates, as the instances first mentioned show, to produce a change of form. The change produced in the cases, to which we have last referred, may be designated as a change of disposition rather than of form. How nearly related, however, in their power and action, form and disposition are, the contents of ch. 58 show. For the continuous effect of a crystal, already formed upon another substance, disposed to crystallisation, has its foundation in a disposition, similar to that which manifests itself in the after-tone of a bell that has just been struck, and in the increasing capability of a musical instrument to produce music, the whole fabric of the instrument often being set vibrating harmoniously by a master hand.

Like heat, so do those other motions of the external world, proceeding from the mutual action of polarised opposites, effect changes in the disposition of individual bodies. What mechanical motion, and still more what electricity and magnetism may effect, we have already mentioned. *Becquerel* produced the same change in carbonate of lime with electricity, as with heat. Of the influence which light has upon the disposition of bodies, in addition to the instances already adduced, we will give one more. Phosphorus, which, in its ordinary state, is of a trans-

lucent, yellow color, and fusible under 95° F. (28° R.,) when exposed in a vacuum for some time to the effect of light, is changed into a red, opaque body, hard to be fused, and no longer so readily inflamed as before. The violet ray is as effective in producing this change as the ordinary light; the red ray is the feeblest in this respect.

There are at hand, however, other facts, illustrating the development of organic beings, which show how the universal motion in the material world, especially in the form of heat and light, acts upon the disposition and form of things. Although the character of the different species of animals and plants is distinctly and sharply defined, yet the influence of climate produces such changes, that oftentimes we can only with difficulty distinguish differences in these departments. Even man, by long sojourning in the temperate, frigid or torrid zone, suffers so many changes in form and temperament that groundless doubts have been awakened, whether the Negro, the Mongolian, and the European are all descended from the same stock. In the present condition of things, the influence which the determinate form of a plant has upon the form of the new plant, developed from its seed, is in such equilibrium with the more general influence of climate, that the climate is able to effect no change in the main character of the species; the consideration, however, of the abundant remains of a former animal and vegetable world, teaches us that there has been a time when this relation was different, a time, when the might of that universal motion, of which light and heat are forms, ruled so powerfully over the germs of individual beings that even those essential features of form and disposition were changed, upon which the difference of species depends.

60. THE DETERMINATE PROPORTIONS IN WHICH SUBSTANCES COMBINE. (STOICHIOMETRY.)

A drop of ink, let fall into a wine glass of pure water, is gradually diffused through the whole liquid, and so with a second and a third drop; the water takes as much of the coloring substance as we give it, and when we assist the diffusion of the ink by mechanical means, by shaking the glass, the diffusion becomes so uniform, that every drop of water takes just as much ink as another. The same is the case when a grain of salt is thrown into a glass of water. The more salt we give to the liquid the more it takes in all its parts the taste of salt, for the salt is spread uniformly through the water. In these cases the combination cannot be called chemical.

The case is different when substances enter into a chemical union with one another. When a drop of vitriolic acid is put into water in which lime is mechanically dissolved, the acid does not distribute itself uniformly in the fluid, but the sulphuric acid unites with a certain portion of the lime, and forms sulphate of lime or gypsum, which falls to the bottom as a powder, while the rest of the liquid without showing a trace of the sulphuric acid, remains what is was, caustic lime water. With another drop of vitriolic acid, the same process is repeated, until at last all the lime in the water is saturated with the acid and becomes gypsum. But when now, after every particle of lime water has taken its determinate portion of the acid, a new portion of the acid is added, it is not taken up by the powder at the bottom, as the ink was by the water, but it remains mixed with the water, in which the lime was dissolved, without the exhibition of any attraction of the acid for the lime, or of the lime for the acid. In this case, the two elements, uniting to form gypsum, have become altogether different in their qualities. In the union of the two in gypsum, neither the

nature of the acid nor of the lime is to be recognised. The different effects which they both had on the sense of taste, on litmus paper, and other substances, readily affected by acids and alkalis, are wholly lost; a body is formed which is neither lime nor an acid, but a wholly new and third substance. The gypsum, thus artificially made, is found as one of the common constituents of mountain masses in the most opposite countries and quarters; but when the gypsum from Persia and Egypt, from America and New Holland is chemically analyzed, it is always found to be a combination of lime and sulphuric acid, united in the proportion, to speak in round numbers, of 13 in weight to 18; while in all kinds of minerals, in all the varieties of carbonate of lime, from whatever region they come, whatever may be their form, the relation of the earth to the acid is, in round numbers, as 13 to 10. The amount in weight of carbonic acid, which lime requires for its saturation, is consequently proportioned to the amount of sulphuric acid required therefor, as 5 to 9. Barytes requires indeed a less quantity of the acid to saturate it than the lime; but the proportion of the barytes remains the same, for something more than 17 parts of barytes take up 5 parts of carbonic acid, or 9 parts of sulphuric acid. But these acids are not simple substances, but are composed of carbon or sulphur and oxygen. And here also there is a fixed proportion in weight, for 6 parts of carbon with 16 parts of oxygen form carbonic acid; 16 parts of sulphur with 24 parts of oxygen, sulphuric acid. Hydrogen also combines with these three substances; with carbon in the proportion of 1 to 6, with oxygen, 1 to 8, with sulphur, 1 to 16. Here as there, between carbon, oxygen and sulphur, the same proportion is presented in the numbers 3, 4, 8. Copper and zinc combine with much smaller quantities of oxygen and sulphur, but the weight of the last two substances, which are necessary to their saturation, have the same ratio, for 4 parts

of copper or zinc take up one part of oxygen, or two parts of sulphur. In a similar way, the oxyde of molybdœnum consists of 6 parts of the metal and 1 part of oxygen; of sulphur this metal takes just double, namely, a third. In the case of wolfram, the proportion to these two substances are as 12 and 6 to 1. And thus, when the weight is known, by which any one of the substances mentioned in ch. 14, enters into chemical combination with another, it may be calculated exactly what quantity of one of the other substances it requires for its saturation. If, for example, it is merely known from the analysis of chloride of silver, that the silver is united in it as 3 to 1 of chlorine, it may be ascertained that this substance combines with lead in almost the same proportion, but with copper as 177 to 160, with soda in common salt, almost as 3 to 2, with sulphur nearly as 1 to 2, with oxygen as 44 to 10, finally, with hydrogen as 354 to 10. All this results, on the other side, from knowing that in the oxyde of silver 13½ parts of metal are combined with 1 part of oxygen, in sulphuret of silver 6¾ parts of metal with 1 of sulphur.

But substances are not restricted to combinations in single proportions, but two substances frequently combine in several, forming bodies of separate, independent properties. But it is always observed, that the proportion of any substance, in its higher combinations, is always a multiple of its proportion in a lower combination. Thus 14 parts of nitrogen unite with 8, 16, 24, 32 and 40 parts of oxygen, respectively, forming bodies all differing in their properties. The higher combining proportions of oxygen are, in this case, all multiples of the lowest, 8, by 2, 3, 4 and 5.

The first discovery and scientific confirmation of the doctrine of determinate proportions of elements, Science owes to two German chemists of the last century, *Wenzel* and *Richter*. Not less important, however, is another discovery, of which we

propose now to speak, the credit of which is due to the French philosopher, so often mentioned, Gay Lussac.

By the analysis of water, the proportion is known with great exactness, in which its two elements combine. It is known that 11.09 grains of hydrogen, in combustion with 88.91 of oxygen, give 100 grains of water; one part in weight of the former gas suffices to furnish 8 parts of the latter with the necessary basis for the formation of a new liquid body. When, however, the two gases of which water is composed, are compared according to their volume, it is seen that the space occupied by the hydrogen, before its union with the oxygen, is exactly double of that occupied by the latter; if just so much hydrogen is to be given to a cubic inch of oxyden as it needs in combustion to compose water, two cubic inches of hydrogen are requisite thereto. Not only in regard to the gaseous substances of water, but as respects all substances, which, before their chemical combination with one another, are of a gaseous nature, it has been observed that the space which they occupy after their combination, is simply related to the spaces occupied by each before combination, and both may be referred to a common unity. If we call this unity a cubic inch, we find that, in many chemical combinations of the gases, one cubic inch of one kind with one, or two or four cubic inches of another kind, forms the new body, whose volume may be one, two, or three cubic inches, in which the peculiar properties of both of the constituents are lost. When the carbon in the common fuel of our hearths is to be burnt, chemically combined with oxygen, it must first be converted by heat into a gaseous form. A cubic inch of this gaseous carbon forms, with a cubic inch of oxygen, the so-called carbonic oxyde gas, but that carbonic acid may be formed, a second cubic inch of vital air must be added. For the chemical penetration of these two measures, one measure of the carbon evaporated by the

heat suffices, all the rest of the oxygen coming into the vicinity of the burning body, remains unchanged, taking no part in the combination. Like the oxygen, so also the gaseous carbon enters into a chemical union with hydrogen, under the name of carbureted hydrogen gas. But while, for the saturation of one cubic inch of oxygen, two cubic inches of hydrogen suffice, four measures of hydrogen are requisite to saturate one of carbon.

The space, which, in all these cases, the new chemical combination occupies, allows us sometimes to determine very clearly the expansion which the gas previously possessed. If only one cubic inch of vital air is at hand to combine with a cubic inch of gaseous carbon, the newly formed carbonic oxyde gas, without suffering any contraction, occupies the full space of two cubic inches; but when to the flame, which furnishes the necessary supply of vital air for the formation of carbonic acid, two cubic inches, instead of one, are given, a condensation takes place, the gaseous fluid has the volume of two cubic inches instead of three. From the combination of two parts of hydrogen and one of oxygen, there can be formed not only liquid water, but also a gaseous body, (literally speaking, water gas,) steam. In the formation of this water gas, the three parts of the two gases, which are consumed in its composition, contract to the volume of two parts; and the four cubic inches of hydrogen, which combine with one cubic inch of carbon to form carbureted hydrogen, occupies, after the combination, only the space of 3 cubic inches, because the hydrogen has condensed thereby to half its original bulk. In virtue of a similar condensation of the same to one third of its usual volume, or of two substances to $\frac{1}{2}$, three measures of hydrogen and one of nitrogen, in combining to make ammonial gas, give only 2 measures, instead of four. With the contraction into a smaller volume, the specific gravity of the new combi-

nations increases, and when the specific gravity of water is compared with that which the two parts of hydrogen, together with the one part of oxygen had before their chemical union, there is found to be, between the average weight of both gases, and that of water, a proportion of 1 to almost 1300. Furthermore, the gravity of substances always manifests itself as an unchangeable indestructible condition of their being, for the new combinations have precisely the sum of the weights which the separate substances had, taken together; water, formed out of 11 oz. of hydrogen and 88.9 oz. of oxygen, weighs exactly 6 lbs. 4 oz. or 100 oz. When chlorine, in combination with sodium has lost its volatile nature, its whole destructive power, when sodium is deprived of its inflammability and its resemblance to a metal, and both have become wholesome salt for man and beast, then not a trace is discoverable of the properties which its constituents possessed, but it weighs precisely the same. For the chlorine weighed $60\frac{1}{3}$, the sodium $39\frac{2}{3}$ per cent., the weight of the salt is exactly the sum of both. Thus, amidst all external changes which the visible form of material things undergoes, that band (gravity) which connects individuals to a higher whole, remains an influence, which resembles that of the all upholding might of the Creator.

Even upon the mutual chemical attraction of substances, gravitation appears, at first sight, to have in itself alone a certain influence. If instead of the much inferior mass of the moon, another body, like Venus, which approaches the earth in size, were placed at the same distance from the earth, they would attract each other more powerfully than the earth and its present attendant; the motion of such a great moon would be much quicker, its revolution much shorter than that of the present moon. Two polished metal plates, when laid upon one another hang together vastly more powerfully, through their mutual attraction than 2 polished tables of wood; a mountain

of iron would attract the vibrating plumb line much more strongly than a rock, just as large, of granite or limestone. In the same way it might perhaps be shown that the heavy metals, such as mercury and gold, or mercury and silver, attract each other, and chemically combine much more powerfully, and of course in greater masses (almost as 1 to 1) than a heavier and a lighter substance, (silver and oxygen.) Upon more exact consideration, however, we soon find that it is not specific gravity alone, which determines the measure of chemical attraction; for a rule, which one should base upon this idea, would stumble at every step upon exceptions. On which account, Gay Lussac's discovery, according to which some substances, whose gaseous form admits of admeasurement, combine in proportions in which bulk and expansion are of special importance, appears to us to point nearer to the truth. There is a certain proportion of form and size, on which the measure of chemical attraction may be based; a proportion which extends to the infinitely small particles, (the so-called atoms,) of substances, and is connected with susceptibility of polarisation. If, according to the most intelligible idea, the atoms are supposed to be of different sizes, and consequently of different gravities, their chemical attraction is then analogous to the laws of universal attraction and gravity. The inorganic world is at once the domain of regular, well-defined form, of the prevailing force of gravity, and of electro-magnetic polarities. In many kind of crystals, the ground-form of their shapes may be recognised by mere mechanical divison of their parts, as the cube in galina, the rhomboid in calcareous spar; electric polarisation needs often only a slight excitement from without to awaken it. If in this department we attribute an especial worth to the form and size even of the elementary particles, then may these views lay claim to probability.

61. THE STEPS IN THE DEVELOPMENT OF LIFE.

Organised matter has an advantage over unorganised, in that, in its chemical composition, it is prevailingly formed out of those substances which form the kingdom of the fluid and movable: water and air. The air and water are ceaselessly affected throughout by the light and heat of the sun, and by electric forces. Organised bodies, born of the air, by virtue of their origin and kindred nature, take part in the motions which the influence of the sun, chiefly, communicates to the atmosphere; with every breath of air, with every inhalation of the leaf of a plant, the motion without penetrates into the interior of the living body.

The power by which the living body is developed is indeed kindred to the light, but yet it is a much higher power, for no sunbeam is able to form out of water, air and earth, the organic elements of bread, wine, blood, flesh and nerve, and still less is it able to produce a self-moving being or a plant in which exists the power to generate seed after its kind. With the entrance of the vital principle into the visible world, there begins a new creation, proceeding, not like the light from the sun, from a visible, but from an invisible, super-sensuous cause. Our art has not yet learned from the vital principle its most common and public secret, the production of organic elements from inorganic substances; our intelligence tracks in vain the mysterious soul or life of things; we can seize the instrument by which it lets itself be perceived, we can destroy its visible body by physical force; we cannot, however, affect or change itself. Like a child who tries to clutch the reflection of the light as it glances from a mirror on the wall, philosophy in all times has in vain attempted to detain the soul in its fugitive career, and make it an object of direct examination.

As we accompany the principle of life from the lower stages of its development upwards to higher steps, and at last to the highest in the nature of man, it appears to us, the higher we go, less and less at home in the terrestrial world; it is related to the latter ever more as a passing guest and stranger, who has his home in a higher kingdom of being and motion. Especially does the duration of life and the resistance which the vital power makes to its separation from the body, decrease from step to step.

That huge Indian fig-tree (Banana tree) on the shores of the Nerbudda in India, whose outspread, giant branches, bending ever downwards and taking root in the soil, are sufficient, it is said, to give shade to a company of 7000 pilgrims, is without doubt, according to a modern English traveler, the same which the Greek *Nearchus* tells us was an object of wonder in the time of Alexander of Macedon. And an age of yet more than two thousand years must be attributed to the giant trunk of the old Adansonia or Ape-bread-tree in Africa. The great plantain at Cos (Stanco) every year produces its leaves and ripens its seeds as freshly as, according to a not improbable tradition, in the time of *Hippocrates*. In the neighborhood of many of our old lindens the race of man has been renewed perhaps thirty times; thousands have been born and have run the course of life through joy and sorrow to the grave, but the tree, planted beyond the memory of man, still maintains its place in fresh vigor. So intimately has the vital principle, upon this apparently low step of organic development, allied itself with the dead mass of the planet, that it holds fast to this dwelling-place almost with the tenacity, with which the crystallising principle, which has shaped the stone, clings to the elements of the stone; the tree emulates in duration the sand stone rock, into which it strikes its roots, and thus impressively carries on, *out of* its own indwelling force, the work of creation. Among

the lowest forms of the animal world also, the duration of the vital power is almost invincible.

Quite otherwise is it with the higher forms of animal development. These, unlike plants, are rooted not immediately in the elements of the planetary mass, but they obtain their continued subsistence chiefly from the department of organic being standing below them, from the vegetable world, and even from animal life most nearly related to them. They require for their nourishment, elements already organised, and with these sources of life, subject in themselves to continual change and decomposition, these higher forms of organic life share the lot of mutability; they are, in respect to their vital power, of far less duration than the Indian fig-tree or even the soft-wooded linden. But at the same time a new fact is herewith presented. To the nature of the perfect animal other roots are furnished than to the plant, roots, which do not, like the tree, strike downwards and fasten themselves in the soil of the planet, but which spread out in a sphere of higher natural powers, and there find their hold. Such roots are the organs of sense, which receive the impressions of the light, the vibrations of bodies, mechanically, electro-magnetically, or chemically affected.

Hence onwards the creative power of the vital principle (or soul) shows itself in a wholly different and higher mode than in the sphere of vegetable life and in the work of mere material formations. A miracle which our art cannot imitate, our wit fathom, is exhibited in the change of the planetary elements into the juice of grapes, the oil of the olive-tree, or into the flour of the grain. A miracle is that web, so beautifully woven for the purpose of life, of vessels, fibres, of breathing leaves, or lungs, and the production of the vital germ, the fruitful seed of a future generation. But in all these works of formation the soul appears confined to the little circle of its own embod

ment; the material, which it collects from without and applies to its creations, serves only to complete the structure of a certain form; the whole vital activity remains limited in the direction and measure of that motion which was communicated to it at its generation; the soul, however, advances to new miracles of its creative power in the animal gifted with the more perfect organs of sense, and especially in the nature of man. It here receives power to take a self-active share in other works of the Creator besides that which gave it its body and life. When in the darkness of the night I recall the impression which a bright landscape or a visible object, that has deeply interested me, made upon my eye, how could I do so but by a sort of re-creation by my own soul of the world of things of which I think, and of a light like that of the sun, which illuminates this interior world.

With the power of perceiving and knowing the works of the Creator, the human soul receives the power of imitating these works in the sphere of its inner activity, and of creating the same according to its measure. The world of our remembrances and ideas appears indeed, in reference to the outer world, whose forms and motions it comprehends, only as a reflection in a mirror to the actual form that stands before the mirror, but it is nevertheless a world by itself, of vastly longer duration than the Indian fig-tree on the shores of the Nerbudda, or the dried bulb which has been taken from the hand of an Egyptian mummy, and which, after the lapse of thousands of years again produces leaves and blossoms when placed in a moist soil. Of all the elements, of which the soul forms its body, not one remains unchanged in the course of a year or a day; new nutriment enters the body, is converted, under the influence of the vital principle into new blood, new flesh; the old is dissolved and removed from the body; even the solid bone is not excluded from this continual change and renewal;

we have indeed the same eyes and the same hands, but the material of which they are composed, is, after a short space, superseded by new material. The stuff of which our remembrances are made up, on the other hand, remains ever the same, indeed it is specially remarkable that the recollections of childhood are precisely the most vivid and strong in the mind of the old man. And the miracle of this inner creation goes yet further; in the world of our thoughts and recollections dwell creatures and beings, older than the Egyptian pyramids, older than the thick stemmed Adansonia in Senegal, and destined to remain unchanged when those pyramids and trees are no more. The working of such miracles is made possible to the mind through language. By words, written and spoken, we become acquainted with the life and works of the patriarchs of our race, with the fortunes of the kings who built the pyramids. What we hear and read of the deeds of an Alexander or an Augustus, takes in our minds the substantial form of ideas and recollections, and continues as freshly there as if it had passed before our eyes yesterday or to-day. The lapse of thousands of years cannot affect it. Achilles has there remained a youthful hero, Astyanax a blooming boy, such as they were when the fight raged round the walls of Troy. And not only things human, not only the perishable in its material body endures in the inner, spiritual creation of our thoughts,—this creation embraces yet another, infinitely higher domain of being: it comprehends the knowledge of the Creator and of his eternity itself. In the power of the mind to cherish these thoughts of eternity, to know God according to the measure of our creaturely intelligence, lies the surest pledge of the continuance of our being after the death of the body, of an eternal life of the spirit. For only that which is of a kindred nature can comprehend its like. Were there not a sort of fountain of light in our seeing nerve we could see no light; were not the

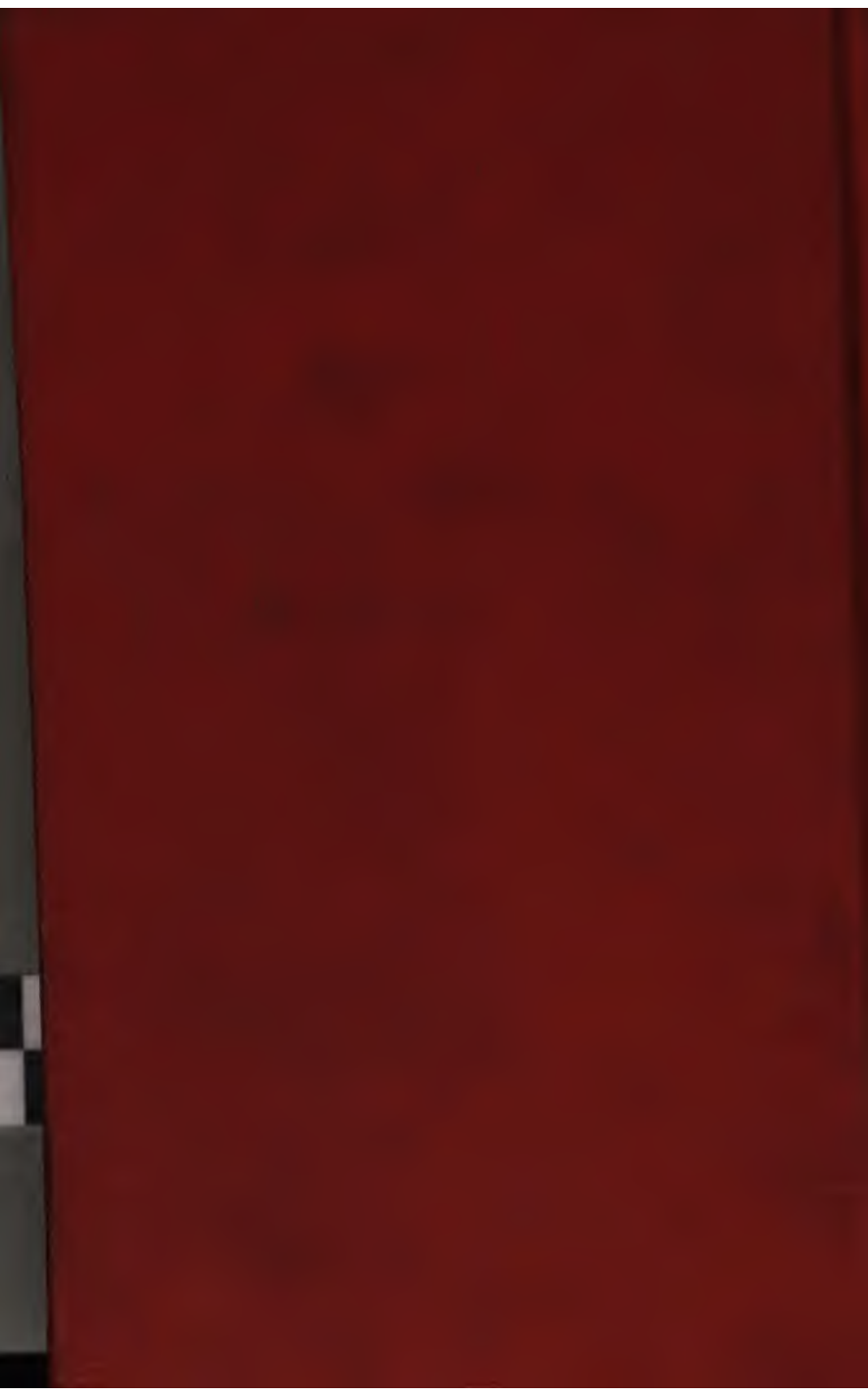
thinking spirit itself of an eternal and divine nature, it could know and apprehend nothing of God and eternity. Thus we find, that the soul, in the higher spheres of its unfolding, from the plant and the lower animal up to the form of man, appears in the material world only as a swiftly passing stranger and guest; that the bands, by which it is connected with its body grow ever frailer, and its life in time more transitory, but that with the perishable body of clay, it has received yet another body, the world of its ideas, which is formed not of a perishable but of an incorruptible material. The visible body may then waste away after a short life-time, there yet remains to us an invisible and eternal body.

The relation of the soul to this higher body of its thoughts, its strivings, its aspirations and its hopes, is a faithful representation of the relation in which the Creator himself stands to the agencies and works of creation. The ideas and recollections, which form the inner world of the mind, are not the mind itself. They are the work of a creation, to which indeed an impulse and material are supplied from without, but which receives its shaping and inner arrangement through its own power. The same discerning spirit that produces this its peculiar creation when and as it wills, the recollection now of this particular, and then of that incident of its experience, holds it all together; it gives to every thought, to every word the power to bear seed and to generate its like.

Over the world of the spiritual as of the material, there reigns a God and Creator of all. He, the uncreated beginning of all being, needed and needs no impulse from without, no material for the work of his creation; his thoughts ever have been and are realities, every thought of his has become a being and a creature. But this majestic visible creation is not the Creator himself; but all the hosts of heaven, all the suns which the eye beholds, are related to him only as the image of a

field of flowers, which the mind recalls, to the mind itself. But these countless hosts of stars are not the most exalted of the realised thoughts and volitions of God, but higher yet are those acts of mercy and love, in which the Creator descends to this minute creature, man, and offers himself to be known as a friend to a friend, and embraces the poor child of humanity as a mother her babe.

The instinct after knowledge is so deeply rooted, and stirs so strongly in the mind, because, when it once starts on its way, it leads, even after many aberrations, to Him, the knowledge of whom, even with the weakest of its rays, awakens love for Him as the sunlight wakens warmth. And only in this love of God is true life and blessedness.

END.

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